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CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
EXHIBIT "E" Para. 5.1	13	LEM	NAS 9-1100	14 Jan 63

Type II Data

Primary No. 687

CLASSIFICATION CHANGE
To UNCLASSIFIED
By authority of GDS - Eo 11652
Changed by J. Shirley Date 12/31/72
Classified Document Master Control Station, NASA
Scientific and Technical Information Facility

REPORT

NO. LED-520-1C

DATE: 15 May 1963

Rev. 15 Nov 1963

Rev. 15 March 1964

DESIGN CRITERIA AND ENVIRONMENTS [U]

LEM

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CODE [redacted]

A. Shreeves

PREPARED BY:

A. Shreeves

A. Whitaker

A. Whitaker
LEM SYSTEMS
Systems Project Engineer

R A Hilderman

CHECKED BY:

R.A. Hilderman

John Meirs

APPROVED BY:

J. Meirs
Chief of Structures

C W Rathke

C.W. Rathke
LEM Project
Engineering Manager

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS
15 Aug 63	A.S.	Revisions on all pages except pages 3,4,7,9,21,22,24,30,37,39	Current information incorporated.
		Addes pages 5.1, 17.1, 18.1, 46.1	
15 Nov63	A.S.	Major Revision on all pages. Note Line in margin.	Current information incorporated.
15 Mar 64	A.S	Revised Induced Radiation, Meteoroids Vacuum Values, LEM Mission Times.	Current information incorporated
		Little Joe II deleted. Revisions on all pages with lines in margins.	

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

ENG. 345

TABLE OF CONTENTS

INTRODUCTION

This report is presented in partial fulfillment of the requirements of paragraph 5.1 of Exhibit E of Contract No. NAS 9-1100 and contains the natural and induced environments to be used for the design of the LEM and its equipment. The numerical values presented in this issue of the report are preliminary and are intended as a guide to the magnitude of the values and the operational conditions causing them. Revisions to this report will be issued as firm information becomes available.

DESIGN CRITERIA AND ENVIRONMENTS

1. General

1.1 Requirements - The LEM and its subsystems shall be designed to meet the general criteria and environmental conditions herein as well as the particular mission requirements as set forth in the detail specifications.

Design procedures shall be conducted in accordance with recognized rational principles within the following framework.

1.1.1 Design - The purpose of the entire design and test effort is to produce reliable equipment for the lunar landing mission. This purpose is accomplished by analysis and test of the failure modes for each item of equipment during the design development. The objective of this failure analysis is the ability to predict, accurately, not only the type, or mode, of failure but the stress level at which it occurs. The design and failure analyses must go hand-in-hand so that the effect of changing design features on the failure modes will be part of the design trade-off evaluations and the reliability assessment.

Stress level, as used here, means the intensity of any parameter, such as pressure, voltage, temperature, etc. which affects the ability of the equipment to perform its design function. These parameters consist of both the environmental conditions imposed on the equipment and the self-induced conditions due to operating the equipment for the design mission time. Operating time (or number of cycles) should also be considered as a criteria variable. The natural and induced environments given in this report are the maximum levels that can be expected to occurr in any LEM mission. Rational combinations of these environmental and self-induced conditions must be considered in the design of each item of equipment.

The factor of safety, that is, the ratio of the allowable stress to the design stress, must be selected so that the likelihood of failure under the maximum mission level stresses is acceptably remote. The likelihood of failure is due, in part to the range of distribution of strength available; this range being due to material and constructional variations from one part to another. This likelihood, expressed as a probability, leads to the numerical reliability of the item of equipment under consideration.

1.1.2 Tests - The development test program supports the design effort by providing design data, aiding in material, component and part selection, verifying design concepts and safety factors, substantiating design assumptions from breadboard to design freeze, evaluating environmental effects and determine failure modes and operating characteristics under off-design conditions. These tests should locate such critical features as vibratory resonances, intermittent operation and other non-linear anomalies indicative of potential weakness or malfunction as well as the effects of interaction between environmental and operational parameters.

As an integral part of the development test program, stress-to-failure tests will be employed to obtain failure modes and/or safety margins which exist in the flight weight design. These tests, in combination with background data, must provide information which gives us a measure of the unit to unit variability of strength.

The significance of the stress-to-failure tests will be increased by stressing the equipment to failure after exposing it to one simulated mission operating cycle. This simulated mission cycle will include all critical environments and loads due to acceptance and check out testing plus all phases of handling and mission operation.

These tests are a logical extension of the design verification portion of the development tests in that they provide useful information early in the program as well as check on the ability of the equipment to pass qualification tests.

The information from the stress to failure tests as well as other development tests combined with the design analysis, should result in such a complete understanding of the equipment characteristics that the accurate prediction of failure modes can be made. Based on this information the requirements for qualification testing can be firmly established.

1.1.3 Acceptance Tests - The planning for the acceptance tests should begin during the design analysis at the time when it first becomes apparent which are the critical characteristics of the equipment. Thought should be given at this early stage, to non-destructive tests, inspections or operational procedures which will give meaningful information on the presence or lack of adequate strength or operational capability. These concepts should be checked during the foregoing testing to provide the necessary assurance that the objectives of the acceptance tests will be attained. This preliminary set of acceptance test requirements must be complete before equipment qualification since equipment must be "accepted" before it can be "qualified".

The eventual purpose of the acceptance tests is to show that the equipment is representative of and the performance is equivalent to the equipment used in qualification tests.

1.1.4 Qualification Tests - The qualification tests should be planned to demonstrate that equipment that can pass the acceptance tests has the design safety factor and will fail as predicted.

The qualification equipment, therefore, will go through three test phases:

1. The first phase will consist of the acceptance tests derived from the development effort mentioned above.

2. The second phase will be made up of two parts:

   a. The first part will consist of tests to demonstrate the existance of safety factors, as required by the failure analysis, for all critical modes. These tests, of necessity, will be run at stress levels higher than maximum mission level. No failure will be permitted at the qualification level.

   b. The second part will consist of an endurance test performed with mission level environments using operating time rather than stress as the critical parameter to affect the equipment function. The test duration will be equal to or greater than mission simulation life. (A mission simulation life is defined as ground operating time plus mission time).

3. The third phase should consist of tests to failure or malfunction in one or more of the critical modes in order to evaluate the margins above qualification levels.

If, during qualification, a failure should occur which is not at the predicted mode or level a complete evaluation of the failure and the failure analysis shall be made. Pending the results of this evaluation the equipment is not considered qualified and the acceptance tests are invalidated.

1.2 Reliability - The nature of the lunar landing mission requires that crew safety be achieved through overall reliability rather than through the use of escape systems. Therefore, attainment of the maximum mission reliability and crew safety shall be the most important single consideration in the design, construction, handling and operation of the LEM.

For the LEM, the probability goal for accomplishing the mission objectives shall be 0.984. For the LEM, the probability goal that none of the crewmen shall have been subjected to conditions more severe than the emergency limits set forth in the crew requirements section shall be 0.9995.

These reliability goals are to be met including the effects of launch vehicle and spacecraft environments as well as ground complex reliability but excluding consideration of radiation, meteoroid impact and launch vehicle or Command and Service Module operational reliability.

1.3 Advances in Technology - Flexibility shall be incorporated into the design such that advantage can be taken of advances in technology.

2. Performance

2.1 Margins - Rational margins shall be used for systems and components so that the greatest overall design efficiency is achieved within the general criteria stated herein. The specific margins stated below are derived from rational consideration of past and anticipated operational experience. They are to be used as design criteria until experience justifies modification.

2.1.1 Multiple Failure Philosophy - The decision to design for single or multiple failures shall be based on the expected frequency of occurrence as it affects system reliability, safety and weight and shall require specific justification in each instance.

2.1.2 Fail Safe Requirements - System or component failures shall not propogate sequentially, i.e., the design shall "fail safe".

2.1.3 Design Margin - All LEM systems shall be designed to positive margins of safety. No system shall be designed incapable of functioning at limit load conditions.

2.2 Criteria

2.2.1 Repressurization Requirements - The LEM shall be capable of receiving 2 complete cabin repressurizations from the Command Module repressurization system.

The LEM repressurization system shall be designed for 6 complete cabin repressurizations, and a continuous leak rate as high as 0.2 lbs. per hour. Provisions shall be made for a total of 6 recharges of the portable life support systems.

2.2.2 Vacuum Operation of Cabin Equipment - Equipment which is normally operated in the pressurized cabin environment shall be designed to function for a minimum of two days in vacuum without failure. Time period in vacuum prior to operation shall be a minimum of 5 days.

2.2.3 Mission Abort - Provisions shall be made for crew initiation of all mission aborts. Initiation of abort by ground command or automatic system shall be provided when this enhances crew safety. All aborts during lunar excursion shall provide for return to, rendezvous, and docking with the Command and Service Modules.

2.3 Mission Profile -

2.3.1 Ground Handling and Pre-Flight Operations

2.3.1.1 Packaged - Transportation of test and flight modules will be from GAEC to point of use. Transportation is expected to be by truck, however, air transport will be considered to reduce shipping time. Ground test Modules will be shipped to Huntsville, Alabama; Houston, Texas; White Sands, New Mexico; and NAA Downey, California. Flight modules will be delivered directly to AMR. Time for transportation by truck is expected to be on the order of one week to AMR and two weeks to WSMR.

2.3.1.2 Unpackaged - For flight modules, an acceptance checkout and assembly will be performed at the launch sites as well as hot firing of its propulsion and reaction control systems. Assembly into the Launch Vehicle will occur on the launch pad for C-1B flights. Assembly for C-5 flights will occur in the vertical assembly. Prior to prelaunch operations at AMR the LEM and its subsystems will undergo acceptance tests at Grumman. LEM subsystems will undergo vendor acceptance tests prior to being delivered to Grumman.

2.3.2 Launch Vehicle - First stage thrust time from hold-down release to burnout is about 135 seconds, maximum q occurs at about 65 seconds. Second stage burning time is approximately 400 seconds. The Launch Escape System will be jettisoned shortly after ignition of second stage. Third stage burning time will be about 160 seconds to place spacecraft in parking orbit. The third stage is restartable and after re-ignition will have a burning time of 320 seconds for translunar injection. Dynamic loads to be encountered are due to thrust changes, maneuvering, gusts and engine induced vibration. Total thrust time is (135 + 400 + 160 + 320) = 1015 second or 17 minutes.

2.3.3 Spacecraft - Immediately after translunar injection, the Command Module/Service Module is separated from the LEM shroud and the upper shroud is jettisoned. The CM/SM is then re-oriented to mate with the LEM at the upper LEM hatch. During this maneuver the CM/SM is the active member and the LEM remains attached to the empty S-IVB. After transpositioning, the S-IVB and lower shroud is separated from the spacecraft and translunar attitude is established for the lunar trip. Trajectory corrections are applied periodically by the Service Propulsion System with the first correction occurring about 2 1/2 hours after injection. Following this course correction a complete checkout of LEM is made with one crew member transferring from the Command module to LEM. At about 115 hours the SM propulsion system established the spacecraft in a circular lunar orbit at 80 nautical miles altitude. The crew is transferred and after a system check, the LEM is separated at about 119 hours after launch. The LEM is the active member during Descent, Landing, Ascent, Rendezvous and Docking. After crew transfer to the Command Module the LEM is jettisoned and left in lunar orbit.

For summary of LEM mission time, see Table I.

2.3.4 Lunar Excursion - The Lunar Excursion Module shall have the capability of performing the separation, lunar descent, landing, ascent, rendezvous and docking independent of the spacecraft. All LEM systems shall be capable of performing at their nominal design performance level for a mission of two days without resupply. Lunar descent will be by elliptical orbit ending at a lunar altitude of 50,000 ft. after which a powered descent will end in a hovering maneuver which may require translations up to 1000 ft. and may last for two minutes. Final touchdown horizontal velocity shall not exceed 5 ft./sec., and vertical velocity shall not exceed 10 ft./sec.

2.3.5 Lunar Ascent - The powered ascent of the LEM ascent stage to the 50,000 ft. altitude circular orbit shall take 7.3 minutes. A 9 hour orbital contingency at 50,000 ft. will be available to permit the insertion into a rendezvous trajectory at 30 nautical mile altitude. The total ascent time, including the 9 hour orbit contingency, shall take 11.61 hours, during which time all ascent stage systems shall be capable of performing at their nominal design performance level.

3. Design Criteria

3.1 General

3.1.1 Design Flexibility - The LEM shall be designed such that additional or lesser requirements in thermal resistance, meteoroid protection and radiation protection may be accommodated or taken advantage of without overall design changes.

3.1.2 Isolation of Modifications - The LEM and its component subsystems shall be designed such that general modifications to the LEM module or its subsystems do not propogate through the other modules of the Apollo spacecraft.

3.2 Structural Requirements For LEM & LEM Items *

3.2.1 Design Factors

3.2.1.1 Purpose and Definition of Safety Factors - The level of structural strength and stiffness is established by the conditions of 3.3, 3.4 and 4.0 in addition to specific loadings applicable to particular subsystems. Such loads, called limit loads, are conservatively selected to represent the maximum range of severity expected on the lunar mission. Rational allowance shall be made and incorporated in these loads for stress concentrations, fatigue, thermal stresses and dynamic response. Factors of safety are multiplied by these limit loads to provide precautions against unknown deficiencies in strength as well as against excessively severe loadings, in order to keep the probability of failure within the necessary limits.

Ultimate Factor - At limit load ** times the ultimate factor of safety there shall be no failure of structural members. The ultimate factor shall be not less than 1.5 applied to limit loads. This value, may be reduced to 1.35 for special cases, not involving pressure vessels, upon rational analysis and with MSC approval.

Yield Factor - At limit load ** times the yield factor of safety there shall be no permanent deformation or total deformation which would prevent performance of the mission. The yield factor, applied to limit loads is nominally 1.35, but may be as low as 1.0 for ductile materials and not involving pressure vessels and need not exceed 1.5.

3.2.1.2 Pressure Vessel Factors - The design of pressure vessels shall be based on two analytical considerations. When external loads are applied in combination with pressure, the factors of 3.2.1.1 above, will apply. When pressure is applied as a singular load, the factors of 3.2.1.2.1 and 3.2.1.2.2 below, will apply.

* See 3.4.1.2 for equipment when in ground support of LEM.

** Combined loadings, acceleration, pressure, vibrations etc, shall be considered.

3.2.1.2.1 Pressure Vessel Proof Factor - All pressure vessels will be subjected to a pressure proof test during acceptance testing. After exposure to proof pressure, the pressure vessel shall be fully capable of performing the mission. The proof factor shall be 1.33 times limit pressure.* This factor may be reduced for special cases upon rational analysis and negotiation with MSC.

3.2.1.2.2 Pressure Vessel Ultimate Factor - At limit load times the ultimate factor of safety there shall be no failure of the pressure vessel. The ultimate factor shall be 2.00 applied to limit loads.* This factor may be reduced to 1.5 for special cases upon rational analysis and negotiation with MSC. (The main propellant and RCS tanks are a special case and will have an ultimate factor of 1.50 on the worst combination of acceleration, pressure,vibrations, shock, etc.)

3.2.1.2.3 Pressure Vessel Limit Loads - Limit loads shall be obtained with limit pressures. Limit pressure shall be no lower than the maximum relief valve pressure for the system. When pressure effects are relieving, pressure shall not be used.

3.2.2 Pressure Stabilized Structures - No primary structures shall require pressure stabilization.

* For Propulsion and Reaction Control System pressurized components downstream of the helium pressure regulators.

Proof press. shall be 2.0 times the maximum expected line pressure (use relief valve maximum) or the combined surge plus nominal maximum pressure, whichever is greatest.

Ultimate pressure shall be 3.0 times the maximum expected line pressure (use relief valve maximum) or 1.5 times the combined surge plus nominal maximum pressures, whichever is greatest.

3.2.3 Vibration - The applied vibrational environment for launch and boost, translunar, descent and ascent phases of the mission consists of random excitation up to 2000 cps. The high acceleration density levels at low frequencies are presented for use in the design analysis only since available test equipment is incapable of reproducing the complete spectrum. The test requirements (Ref. LED-520-5) include separate sinusoidal vibrations to account for this low frequency portion of the spectrum as well as to determine the design adequacy in individual vibration modes. Test requirements should be considered as part of the vibration design. (Table I of LED-520-5 contains the 1.3 factor of 3.2.3.1 below).

Separate launch and boost vibration are given in Table II for exterior and interior primary structure. Exterior structure is that which is primarily excited by acoustics during launch and boost, while interior primary structure is not.

3.2.3.1 Vibration Factors - The vibrational amplitudes given in Table II are estimated as the highest levels that will occur during a mission. Satisfactory operation must be attained with other appropriate amplitudes increased by a factor in combination with other appropriate environments. The value of this factor for pre-launch packaged and unpackaged of Table II, parts (a) and (b), is 1.0 and the value for all other conditions is 1.3 applied on the g and D.A. and $(1.3)^2$ applied to random vibration (g^2/cps).

3.2.3.2. Vibration Amplification - The vibrational amplification factor in the range of the Table II applied vibrations, shall not exceed a value of ten. This amplification factor is defined as the total displacement of any point on an equipment divided by the displacement of the input device.

3.2.3.3. Stiffness of Equipment Mounts - With the exception of individual parts and components, the basic chassis and/or mounting structure of equipment (such as brackets and shelves) shall be free of mechanical resonances below 60 cps.

3.2.4 Other Environmental Factors of Safety - The limit proof and ultimate factors of safety shall be 1.0 for the following environments:

a. Humidity
b. Rain
c. Salt Spray & Fog
d. Sand & Dust
e. Fungus
f. Hazardous Gases
g. Radiation
h. Temperature

3.3 Flight Loads

3.3.1 Launch Vehicle

3.3.1.1 Temperature

3.3.1.1.1 C-5 - Ambient sea level air temperature at AMR during launch time will vary between +15°F. and 100°F. The most likely range is between 56°F. and 83°F.

3.3.1.1.2 Boosted Flight - The temperature/altitude relationship will be according to the U.S. standard atmosphere 1962 (Ref. 10).

3.3.1.2 Pressure - The pressure/altitude relationship will be according to the U.S. standard atmosphere 1962 (Ref. 10).

3.3.1.3 Vibration - Vibration due to launch vehicle operation will be as follows.

C-5: Vibration see Table II (d)

3.3.1.4 Dynamic Loading - Acceleration loads due to booster thrust are as shown in Table IV and Table II.

3.3.1.4.1 Staging - Dynamic loads due to thrust changes are covered by the following: Hold-down release produces ±1.25g superimposed on 1.25g static thrust. Thrust drop off at 1st stage burnout produces -2.6g.

3.3.2 Spacecraft -

3.3.2.1 Temperature - The external surface temperature of the LEM will vary between approximately ±260°F. depending on the orientation of the spacecraft relative to the sun due to space environment of -460°F. and solar radiation of 440 BTU/Ft^2 hr. The temperature will be between 0° to +160°F. in vacuum cabin and equipment bay, +40° to 100°F. in the propulsion compartment, and +70° to +80° in the controlled (O_2) cabin. (Local spots in the cabin 50° to 90°F.)

3.3.2.2. Pressure - The atmospheric pressure in cislunar space will be on the order of 10^{-14}mm of Hg. The controlled cabin pressure is 5 psia O_2 nominal. The uncontrolled pressure is 5 psia to .1 psia O_2 nominal.

3.3.2.3 Vibration - Vibration due to Service Propulsion System will be as follows:

Random Vibration - Reference Table II (e)

3.3.2.4. <u>Dynamic Loading</u>

3.3.2.4.1. <u>Space Maneuvers</u> - Maneuver accelerations due to Service Propulsion System & Stabilization and Control systems are as follows:

X	Lateral	Pitch
N_x	Ny & Nz	$\ddot{\theta}$*
-.45 g	.11 g	.373 Rad./sec.^{2}

3.3.2.4.2 <u>Repositioning</u> - The shock loads due to repositioning after S-IVB burnout are:

N_x	Ny & Nz	$\ddot{\theta}$*
-.32 g	.093 g	.40 Rad./sec.^{2}
-.84 g	.120 g	17.0 Rad/sec.^{2}

3.3.3 <u>Lunar Excursion</u>

3.3.3.1. <u>Temperature</u> - The external surface temperature of the LEM will vary between approximately -260° and +260° depending on the orientation of the sun. The space environment is -460° F. and solar radiation is 440 BTU/Ft.^{2} hr. The lunar surface temperature will be +250° to -300° F. depending on the position of the sun and the location of LEM on the moon. When pressurized the temperature of the cabin will be between 70° and 80° F. The temperature will be 0° to +160° F. in vacuum cabin and equipment bay and +40° to +100° F. in the propulsion compartment. (Cabin local spots 50-90° F.) (The descent engine combustion chamber backface is less than 400°F.)

3.3.3.2 <u>Pressure</u> - The ambient pressure on the lunar surface will not exceed 10^{-10} mm of Hg. When pressurized the cabin pressure of the LEM will be 5.0 psi $\pm$ .20 psi, with a relief valve setting of 5.6 psi $\pm$ .20 psi. The cabin atmosphere will consist of pure oxygen.

3.3.3.3. <u>Vibration</u> - Vibration due to descent or ascent engines are as follows:

Descent - Reference Table II (g)

Ascent - Reference Table II (i)

*NOTE: $\ddot{\theta}$ is rotational acceleration about any axis normal to the x axis

3.3.3.4. Dynamic Loading

3.3.3.4.1 Descent Maneuvers - Dynamic loads during descent are due to the operation of the main descent engine and the Reaction Control System. Significant loads calculated occur at separation, in elliptical orbit, at start of hover and just prior to touchdown. Accelerations are calculated assuming maximum thrust at any time during the 730 second engine duty time.

Phase	Vertical Accel. earth g's X	Lateral Accel. earth g's Y and Z	Rad/Sec^2 about Y and Z	Rad/Sec^2 about X
At Separation	+ .45	±.046	±.20	±.12
Elliptic Orbit	+ .47	±.046	±.20	±.13
Start of Hover	+1.00	±.100	±.42	±.28
End of Hover	±1.10	±.112	±.47	±.31
Transfer Orbit	0	0	0	0

3.3.3.4.2 Lunar Landing - At touchdown the propulsion and Reaction Control systems are capable of producing the accelerations given in 3.3.3.4.1 above. In addition the Reaction Control System combined with the Descent Engine must bring the LEM attitude within 5° of local vertical and must hold the LEM motion within the following limits at impact on the lunar surface. (Ref. 1, Pgs 92 & 137.)

Local Vertical Velocity	Local Horizontal Velocity	Pitch/Roll Rate	Yaw Rate
10 f p s	5 f p s	.25 Rad/Sec.	.25 Rad/Se

Critical impact loads during lunar landing, resulting from the limiting rates given above, occur for the initial leg impact and for the "rock back" or secondary impact.

	Vertical Accel. Earth g's (X)	Lateral Accel. Earth g's (Y or Z)	Rad/Sec^2 about Y or Z
Initial Contact	8.0 (10-20 ms)	0	±14.0
Rock Back	0	±8.0. (10-20 ms)	±14.0

3.3.3.4.3 Ascent and Rendezvous - Loads due to ascent engine thrust and Reaction Control System are critical at minimum weight just before docking. The permissible closing velocities for docking do not exceed the following: Reference 11.

Closing Velocity Z	Side Velocity X or Y	Angular Velocity Any Axis
.1 to 1 ft/sec.	.5 ft/sec.	1 Degree/Sec.

Docking loads are estimated.

	Vert. Accel. g's X	Lateral Accel. g's Y and Z	Lateral Accel. g's Z Only	Rad/Sec^2 about Y and X	Rad/Sec^2 about Z
Maneuver	1.04	±.054	0	±.33	±2.00
Docking	0	0	-4.0	0	0

3.4 Transportation, Ground Handling, and Storage - This criteria presents the natural and induced environments associated with transportation, ground handling and storage for LEM and/or individual item.

Criteria is presented for ground equipment during support of LEM and/or individual items, and when subjected to induced accelerations, shocks and vibrations.

3.4.1 General

3.4.1.1 Definition - For the purpose of this section, a package is defined as follows: The package is the complete ready-for-shipment outer container loaded with its item, and including insulation and other special internal supports.

3.4.1.2 Structural Factors of Safety For Ground Equipment

3.4.1.2.1 Limit Load - Limit loads are service level loads.

3.4.1.2.2 Ultimate Factor - For ground support equipment and shipping containers the ultimate factor is not to be less than 3.0 applied to limit loads. At limit loads times the ultimate load factor of safety, there is to be no failure of structural members.

3.4.1.2.3 Yield Factor - For ground support equipment and shipping containers the yield factor is defined in 3.2.1.1 and shall not be less than 2.0.

3.4.1.2.4 Proof Factor For Pressure Vessels - For ground support equipment and shipping containers the proof factor is defined in 3.2.1.2.1 and shall be not less than 2.0.

3.4.1.2.5 Proof Factor for Slings - All slings will be subjected to a proof load acceptance test. After exposure to proof load the sling shall be capable of performing the required service. The proof factor shall be not less than 2.0 times limit.

3.4.1.2.6 Orientation - The X-axis is the normal vertical axis. The Y and Z are the lateral axes.

3.4.1.3 Other Environmental Factors - Use the factors of 3.2.4.

3.4.2 Package Natural Environments

3.4.2.1 Pressures - Atmospheric pressure corresponding to sea level to 50,000 ft. altitude.*

3.4.2.2 Temperature - -65°F to 160°F.

3.4.2.3 Humidity - 0 to 100 percent relative humidity including condensation.*

3.4.2.4 Rain - Rain as in Method 506 MIL-STD-810-(USAF) 14 June 1962.*

3.4.2.5 Salt Spray - Salt spray as encountered in a beach area (equivalent to a spray of 5% salt solution in water for 50 hours).*

3.4.2.6 Sand and Dust - As in desert and ocean/beach areas, equivalent to 140 mesh silica flour with particle velocity up to 2000 feet per minute.*

3.4.2.7 Fungus - In accordance with 508, MIL-STD-810 (USAF) 14 June 1962.

3.4.2.8 Ozone - Exposure with .05 parts/million concentration (1/2 Toxic limit).*

3.4.3 Package Induced Environments

3.4.3.1 Sustained Acceleration - 2.67 g vertical (X-axis) with 1.0 g lateral (Y, Z axes).

3.4.3.2 Hoisting Acceleration - Two separate conditions:

a) 2.0 g in direction of hoisting

b) 2.67 g Vertical (X-axis) with 1.0 g Lateral (normal to X-axis)

3.4.3.2.1 Hoisting with Lift Rings - The 2.0 g hoisting shall be considered to be applied on any one ring or any combination of rings, whichever is critical.

3.4.3.3 Shock - As in MIL-STD-810 (USAF) 14 June 1962 Method 516 - procedure III. See Table II (a). Shock on Engine in special container see (Ref. 12).

Shock on LEM Vehicle is to be supplied (preliminary 8 g 10-20 ms).

3.4.3.4 Vibration - As in MIL-STD-810 (USAF) 14 June 1962 Method 514-6 see Table II (a).

3.4.3.5 Hazardous Gases - Explosion proofing requirements defined in MIL-STD-810 (USAF) 14 June 1962, Method 511 to protect against fuel leakage.

3.4.3.6 Electro-magneti Interference - In accordance with LSP-530-001.

* Ambient environments external to package.

3.4.4 Unpackaged Equipment Item Natural Environments

3.4.4.1 Pressure - Atmospheric pressure corresponding to sea level (Hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20 psi absolute during preflight checkout).

3.4.4.2 Temperature - -20°F to 110°F ambient air temperature plus 360 B.T.U./ft.^{2} hr. solar radiation up to 6 hours per day.

3.4.4.3 Humidity - 15 to 100 percent relative humidity including condensation.

3.4.4.4 Ozone - Same as 3.4.2.8

3.4.4.5 Rain - Same as paragraph 3.4.2.4 except no direct impingement.

3.4.4.6 Salt Fog - As in MIL-STD-810 (USAF) 14 June 1962 Method 509.

3.4.4.7 Sand and Dust - Same as paragraph 3.4.2.6

3.4.5 Unpackaged Equipment Item Induced Environments

3.4.5.1 Sustained Acceleration - 2.67 g vertical (X-axis) with 1.0 g lateral (Y, Z axes).

3.4.5.2 Hoisting Acceleration - Two separate conditions:

a) 2.0 g in direction of hoisting.

b) 2.67 g vertical (X-axis) with 1.0 g lateral (normal to X-axis)

3.4.5.2.1 Hoisting with Lift Rings - The 2.0 g hoisting shall be considered to be applied on any one ring or any combination of rings which ever is critical.

3.4.5.3 Shock - Will not exceed MIL-STD-810 Method 516 procedure I, 15 g peak but modify shock pulse to a saw tooth 11 ± 1 ms rise, 1 ± 1 ms decay. Suitably padded work bench surfaces will be available for the equipment item. Shock for LEM Vehicle will be supplied.

3.4.5.4 Vibration - Vibration applied along each of the three mutually perpendicular axes (X, Y and Z) successively.

Total vibration time will be determined for each item. Vibration amplitudes and times will be supplied later for LEM Structure, & LEM Vehicle.

For Vibration Levels see Table II (b)

3.4.5.5 Hazardous Gases (Exposed Equipment Only) - Explosion proofing requirement defined in MIL-STD-810 (USAF) 14 June 1962 Method 511 to protect against fuel leakage.

3.4.5.6 Electro-magnetic Interference - In accordance with LSP-530-001.

4.0 General Environmental Conditions

4.1.0 Radiation Considerations

4.1.1 Natural Environment - Charged particle radiation shall not be investigated by subcontractors for effects on LEM equipment design. Power transistors having a low alpha cut-off frequency of_ _ _megacycles or less, may be susceptable to radiation damage and may require special design considerations.

4.1.1.1 Charged Particles - Charged particle fluxes to be used for spacecraft environmental analysis are presented in reference to their sources.

4.1.1.1.1 Solar Phenomena - The hazards associated with an active Sun are presented as a Model Solar Event and the probability of encounter for two specific cases are given below Ref. 10.

4.1.1.1.1.1 Model Solar Event - The Model Solar Event to be used in LEM design is defined, in general, as follows: Ref. 10

$$N(>E) = 19.0N(>30) \text{ exp. } (-12.5P)$$

where

$N(>E)$ = number of protons with energy greater than E.

P = the rigidity, or momentum per unit change, BV.(BV = 10^9 Volts)

$$= \frac{\left[(E + M_oC^2)^2 - (M_oC^2)^2\right]^{\frac{1}{2}}}{e}$$

4.1.1.1.1.2 Probability of Encounter - The general equation of the Model Solar Event is to be divided into two specific cases. (Ref. 10)

Case I: The event in this case is that event obtained by assuming a 1% probability that a mission will encounter more than N protons above a specified energy level. This event is defined by:

$$N(>E) = 4.2 \times 10^{10} \text{ exp.}(-12.5P)$$

Case II: The event in this case is that event obtained by assuming that if an event is encountered that the probability of that event having more than N protons at a specified energy level is 1%. This event is defined by:

$$N(>E) = 15.8 \times 10^{10} \text{ exp.}(-12.5P)$$

4.1.1.1.2 Van Allen Radiation Belts - A description of the Van Allen radiation belts is presented in Fig. 19 (Exhibit B).

4.1.1.1.2.1 Inner Belt - The inner belt is concentrated between the geomagnetic latitudes of 40 degrees north and 40 degrees south. Due to the differences in the geomagnetic and geocentric poles and inhomogeneities in the earth's magnetic field, the bottom edge of the inner zone varies with longitude 200 miles in altitude over the east coast of South America (300° east longitude) to 800 miles in altitude over the East Indies (110° east longitude) and peaks in intensity at an altitude of 1 x 10^4 km from the earth's magnetic axis.

4.1.1.1.2.2 Outer Belt - The outer belt is concentrated between the geomagnetic latitudes of 60° North and 60° South. It starts at the bottom of the inner belt, peaks in intensity at an altitude of 2.2×10^4 km from the earth's magnetic axis, and decreases to a minimum at an altitude of approximately 4.5×10^4 km.

4.1.1.1.3 Space Background - The corpuscular radiation shall be considered as shown in Figure 26 of Exhibit B which represents the cosmic ray flux.

4.1.1.2 Electromagnetic Radiation - Electromagnetic radiation to be used for Spacecraft environmental analysis is presented in reference to its source.

4.1.1.2.1 Solar Radiation - The electromagnetic radiation from the Sun covering the spectrum from 60 angstroms to 1300 angstroms is given in Figure 21, from 1300 angstroms to 2000 angstroms is given in Figure 22, and from .2 microns is given in Figure 23 of Exhibit B.

4.1.1.2.2 Earth Radiation and Reflection - The Earth's albedo shall be considered as 35 percent. The remaining 65 percent shall be considered to be absorbed and some re-emitted as thermal radiation. The spectrum for the Earth's albedo at local noon is given in Figure 24 of Exhibit B. The radiation at the center of the dark side shall be considered to originate from a 251° K black body.

4.1.1.2.3 Background Radiation - The background radiation from celestial sources shall be considered to be 10^{-4} ergs/(cm^2 x sec) in the interval 1230 to 1350 angstroms.

4.1.1.3 Protection Criteria

4.1.1.3.1 Radiation Exposure Limit - The nominal biological dose limit shall be the average yearly exposure tabulated in Figure 5 of Exhibit B. The emergency dose limits shall be the maximum permissible, single acute emergency dose as tabulated in Figure 5. The biological dose of paragraph 4.1.1.1.1.2 shall be calculated and compared with the dose limit given. If the dose exceeds the emergency limit, MSC must be notified.

4.1.1.3.2 Models of the Radiation Standard Man - Dosage calculations shall be based on the model presentation in Figure 6 of Exhibit B.

4.1.1.3.3 Materials - The effects of exposure to the Solar Event of paragraph 4.1.1.1.1.2 shall be evaluated and materials selected wherever possible which are unaffected. Where materials must be used which deteriorate or malfunction due to radiation exposure, an evaluation must accompany the request to MSC for approval of the material.

4.1.1.4 Natural Radiation Mission Environment - The charged particle fluxes in the Van Allen radiation belts plus all of the sources of electromagnetic radiation enumerated in Section 4.1.1.2, shall be considered for Earth orbital missions. The complete natural radiation environment enumerated in Section 4.1.1, excluding the Van Allen radiation belts, shall be considered for lunar missions.

4.1.2 Induced Radiation Considerations

4.1.2.1 Radio Frequency - The following radio frequency energy will be present due to the operation of spacecraft equipment. The output power is effective at the antennae.

ITEM	FREQUENCY	POWER
DSIF	2100-2300 mc/sec	20 Watts
Voice Communication	250-300 mc/sec	10 Watts
Tracking Radar	X - Band	500 Milliwatts
Landing Radar	X - Band	400 Milliwatts
Transponder	X - Band	100 Milliwatts

4.1.2.2 Thermal - When the environmental control system is operating, the cabin atmosphere will be at a temperature of 70 to 80 degrees F. This atmosphere will be 100% oxygen at a pressure of 3.5 to 5.0 psi. The relative humidity will be between 40% and 70%.

4.1.2.3 RCS Exhaust Plume - RCS exhaust plume effects shall be considered during Translunar, Descent, and Ascent. Plume heating effects shall be in accordance with Figure 8.

4.2.0 Meteoroid Considerations

4.2.1 Environment - The meteoroid environment for the LEM mission consists of both sporadic and shower activity as given below. (Ref. 15) The combined hazard shall apply the time of trans-positioning to start of lunar orbit (6 to 9, page 30). The sporadic hazard shall apply from lunar orbit to the end of the mission.

(1) Sporadic Meteoroids

$$\text{Log}_{10}N = -1.34 \log_{10}M - 10.423$$

Density = 0.5 gms/cc, all sizes
Velocity = 30 km/sec, all sizes

where N = number of impacts per square foot per day of mass M or greater

M = mass in grams

(2) Shower Meteoroids

$$\text{Log}_{10}N = -1.34 \log_{10}M - 10.423 + \log_{10}F$$

Density = 0.5 gm/cc, all sizes
Velocity = as noted in Table V A
Direction = as noted in Table V A
F = ratio of shower to sporadic rates are given in Figure 4

4.2.2 Penetration Mechanics - The Summers penetration equation will be used in sporadic and shower meteoroid penetration applications for finite thickness and double-wall structures. This equation, which includes a 50% increase in skin thickness over penetration depth in order to stop the meteoroid, is defined as follows:

$$\Sigma t_1 = 4.24\, K \rho_m^{1/3}\, M_p^{1/3} \left(\frac{V_m}{C_t\, \rho_t} \right)^{2/3}$$

t_1 = individual finite - sheet thickness, cm.
K = multi-sheet efficiency factor (Table V B)
M_p = penetrating meteoroid mass, gms.
V_m = meteoroid impact velocity, Km/sec.
C_t = target material sonic velocity, Km/sec.,
$C = \sqrt{E/\rho}$, E = elastic modulus
ρ_m = meteoroid density, gm/cc
ρ_t = target material density, gm/cc

4.2.3 Protection Criteria - A design evaluation will be conducted to assess the probability of no meteoroid penetration of critical exposed areas. This study will utilize the sporadic and shower fluxes of 4.2.1 and the penetration resistance equation of 4.2.2. The meteoroid impacts will be considered to occur normal to the surface under investigation. Separate probabilities will be determined, by month, for the sporadic environment and for the sporadic plus showers. Utilizing the known thickness of the exposed surface of the item under consideration and the appropriate velocity from either 4.2.1 (1) or Table V A, the equation of 4.2.2 will give the critical meteoroid mass, M. By entering the equations of 4.2.1 (1) or (2) the critical rate N is found. The relation $P = e^{-NAT}$ gives the probability of no penetration where A is the exposed area in square feet and T is the time in days. Having found a probability for shower and sporadic hazards the total is found from $P_T = P_1 x P_2$. The total exposed area will be used for sporadic meteoroids and the critical projected area will be used for showers. In determining the probability of no penetration due to sporadic meteoroids, Fig. 6 may be used. In Fig. 6 the single skin thickness is taken as the summation of thickness divided by K from Table V B. Since Fig. 6 is based on the average annual flux the ratio R, Fig. 7, should be used to calculate the monthly probability. $P_{month} = 1 - (1-P_{annual})R$. Tank walls that are stressed due to fluid pressure contained therein are not to be considered as forming a part of the meteoroid shield (crew cabin wall excluded).

Meteoroid environment shall not be investigated by subcontractors for effects on LEM equipment design, except for effort during negotiations. Subcontractors will be advised if effort is required.

4.3 Lunar Surface Model

4.3.1 Gravity - The mean acceleration due to the moon's gravity at the surface of the moon is 162.0 cm/sec^2 (5.315 ft/sec^2). This is equivalent to 1/6.0535 times the standard surface gravity of the earth.

4.3.2 Pressure - The atmospheric pressure of the moon does not exceed 10^{-10} mm of Hg.

4.3.3 Thermal - The surface temperature varies between +120°C (250°F) on the bright side to -185° (-300°F) on the dark side of the moon. The solar radiation is 440 BTU/sq. ft./hr. The thermal albedo is 0.124. The thermal conductivity (k) of the lunar surface layer is on the order of 10^{-4} Cal/sec/cm/°K with a density (ρ) of .1 to .3 gm/cm3 and a specific heat (c) of .1 to .2 Cal/gm°K. The product of kρc is on the order of 10^{-6} Cal^2/sec/cm^4/°K^2.

4.3.3.1 Visible Albedo - The visible albedo of the lunar surface has an average value of 0.07. The local value is as low as 0.06 in some crater floors and as high as 0.18 on mountain slopes.

4.3.4 Landing Site Topography - The small scale topography to be used for the LEM landing site is shown in Figure 3, which is same as Figure 24a of Exhibit B of the LEM contract. The surface bearing strengths assumed for design are 12 psi, for the dust layer, 200 psi for the rock froth and 400 psi for the semi-continuous rock layer. The data of this paragraph and of 4.3.3 is currently under study for verification.

4.3.4.1 Landing Site Engineering Design Model - Since the lunar surface varies considerably the following engineering design model will be used in configuring the landing gear: Ref. 16

Slope - (Referenced to local horizontal) $= 5° + \dfrac{24''}{2R_{OT}}$ (57°)

Where R_{OT} = Overturning Radius

This is an "effective slope" that is it includes any depressions, protuberances or soils mechanics effects. Reference Figure #3.

Protuberance Height = 24" maximum - measured up from the highest plane formed by the gear pads.

Bearing Strength - Pads sized to support the LEM on a 12 PSI surface for the maximum vertical ground reaction.

Coefficient of Friction - Sliding 0.1 to 0.8 and fully constrained. Assume constant for any given stability plot.

The maximum horizontal velocity is 5 feet per second in any direction and stability is to be assured under these conditions.

4.4 Human Tolerance Limits

4.4.1 Carbon Dioxide - The carbon dioxide partial pressure nominal limit shall be 7.6 mm of Hg. Maximum. The emergency limits shall be as indicated in Figure 2 of Exhibit B.

4.4.2 Cabin Temperature - The cabin temperature non-stressed limits shall be 70°F minimum and 80°F maximum.. The stressed and emergency limits are presented in Figures 3 and 4 respectively of Exhibit B.

4.4.3 Cabin Relative Humidity - The cabin relative humidity non-stressed limits shall be 40 percent minimum and 70 percent maximum. The stressed and emergency limits shall be as indicated in Figures 3 and 4 respectively of Exhibit B.

4.4.4 Radiation Limits - The radiation limits shall be a specified in 4.1.1.3.

4.4.5 Noise - The noise non-stressed limit shall be 80 db overall and 55 db in the 600 cps to 4800 cps range. The stressed limit shall be the maximum noise level which will permit communications with the ground and between crew members at all times. The emergency limit is presented in Figure 7 of Exhibit B.

4.4.6 Vibration - The vibration stressed, non-stressed and emergency limits are presented in Figure 8 of Exhibit B.

4.4.7 Sustained Acceleration - The sustained acceleration limits shall be as presented in Figures 9, 10 and 11 of Exhibit B. The sustained acceleration performance limits are defined as the maximum sustained acceleration to which the crew shall be subjected and still be required to make decisions, perform hand controller tasks requiring visual acuity, etc.

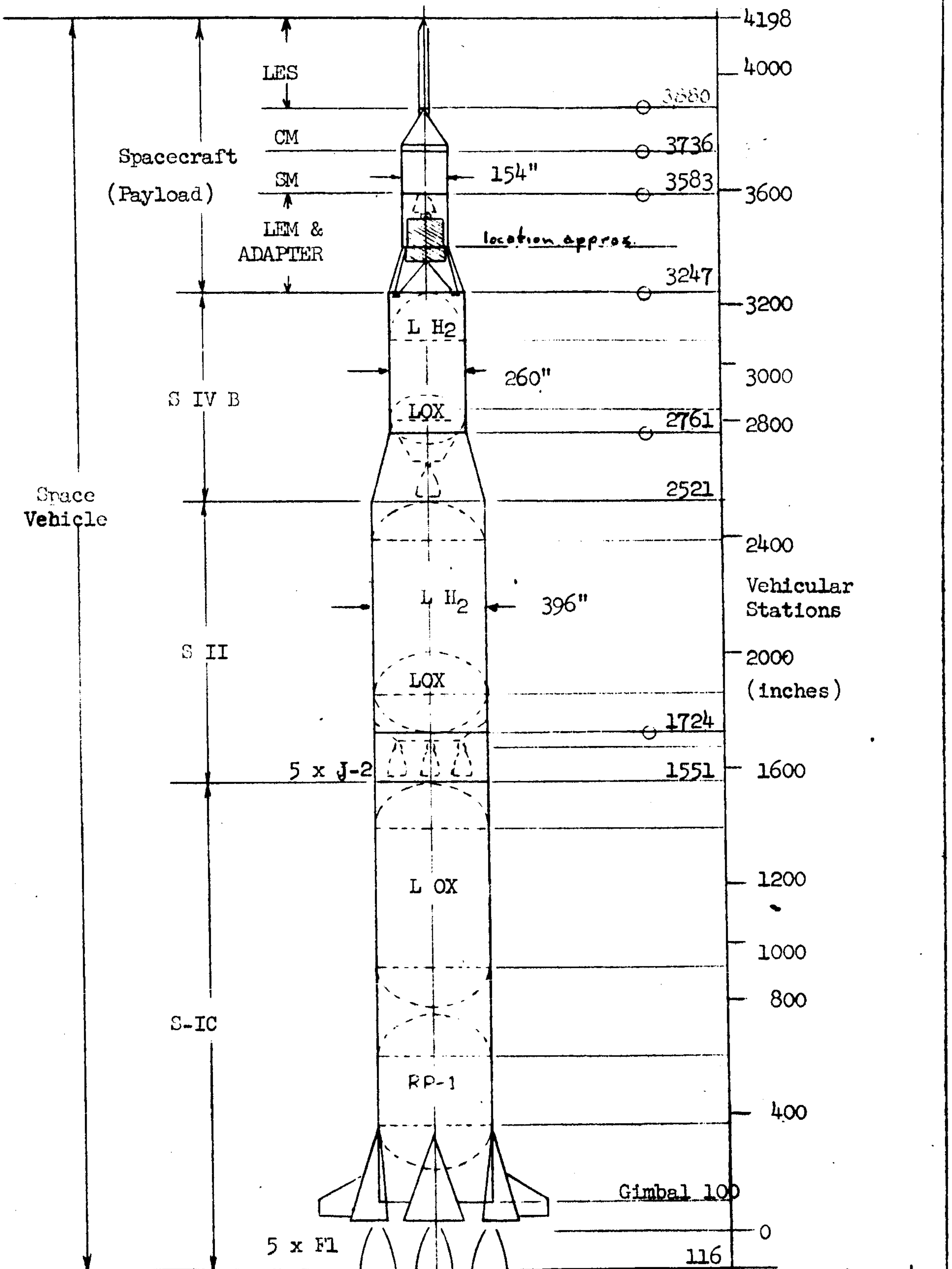
4.4.8 Impact Acceleration - The impact acceleration nominal and emergency limits shall be as indicated in Figures 12 and 13 respectively of exhibit B.

5.0 Summary of Simultaneous Conditions - Table II.

6.0 Weight and Balance - Table III.

X

FIG. 1



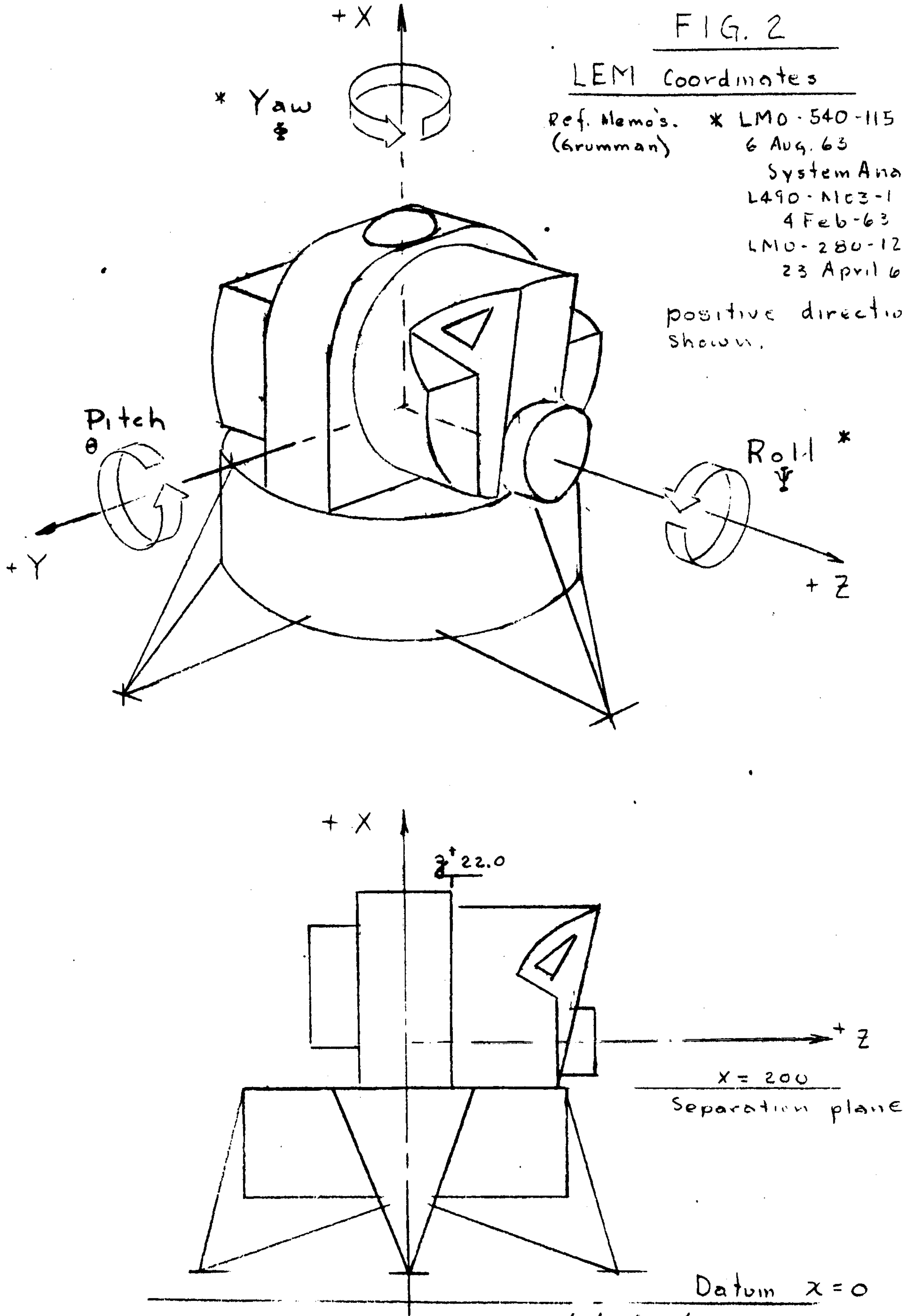
(Ref. Tech. Brief LEM) Apollo, Saturn C-5 Configuration

FIG. 2

LEM Coordinates

Ref. Memo's. (Grumman)
* LMO-540-115
6 Aug. 63
System Analysis
L490-MC3-1
4 Feb-63
LMO-280-12
23 April 63

positive directions shown.



not to scale

FIG.3

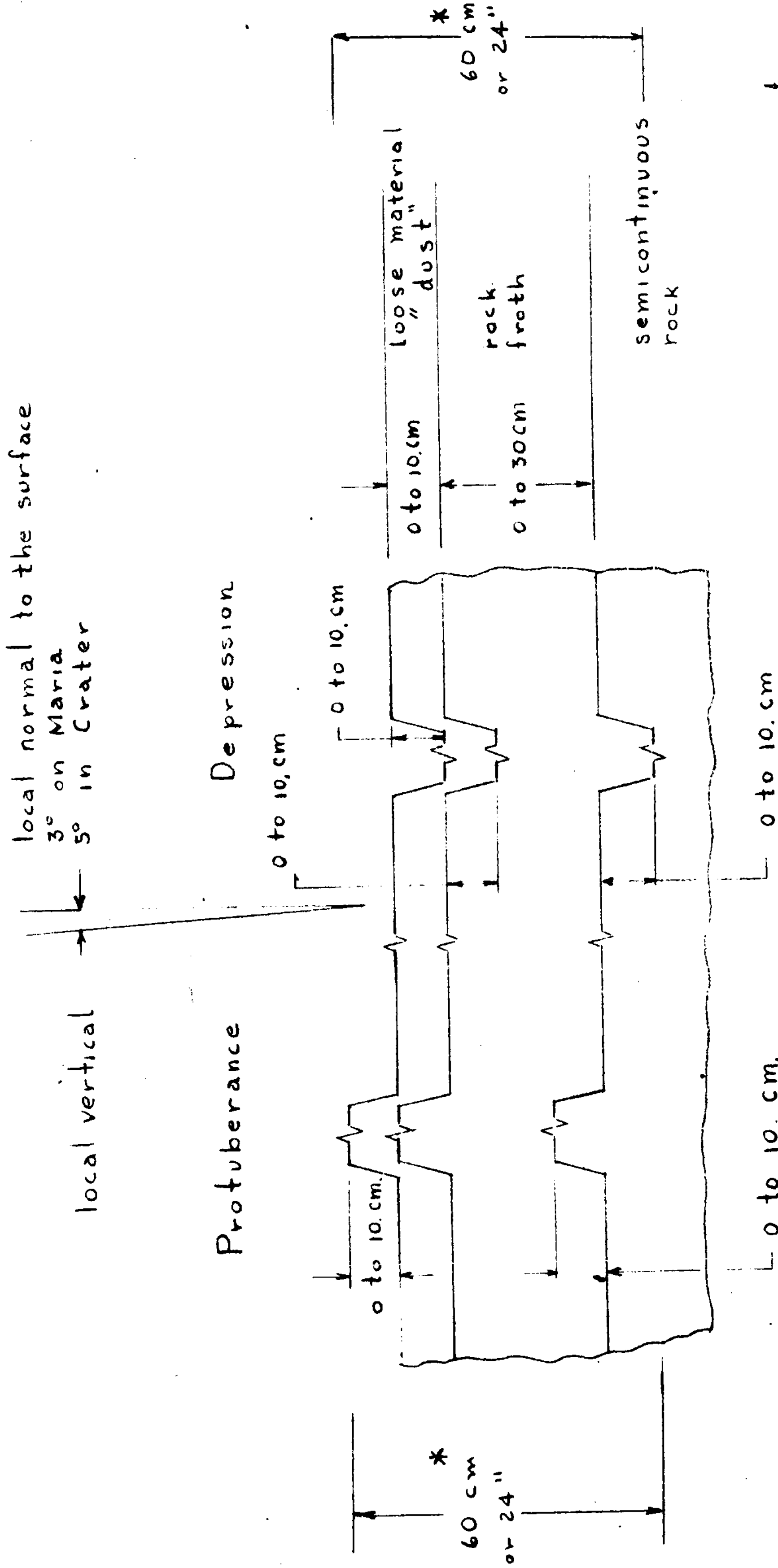
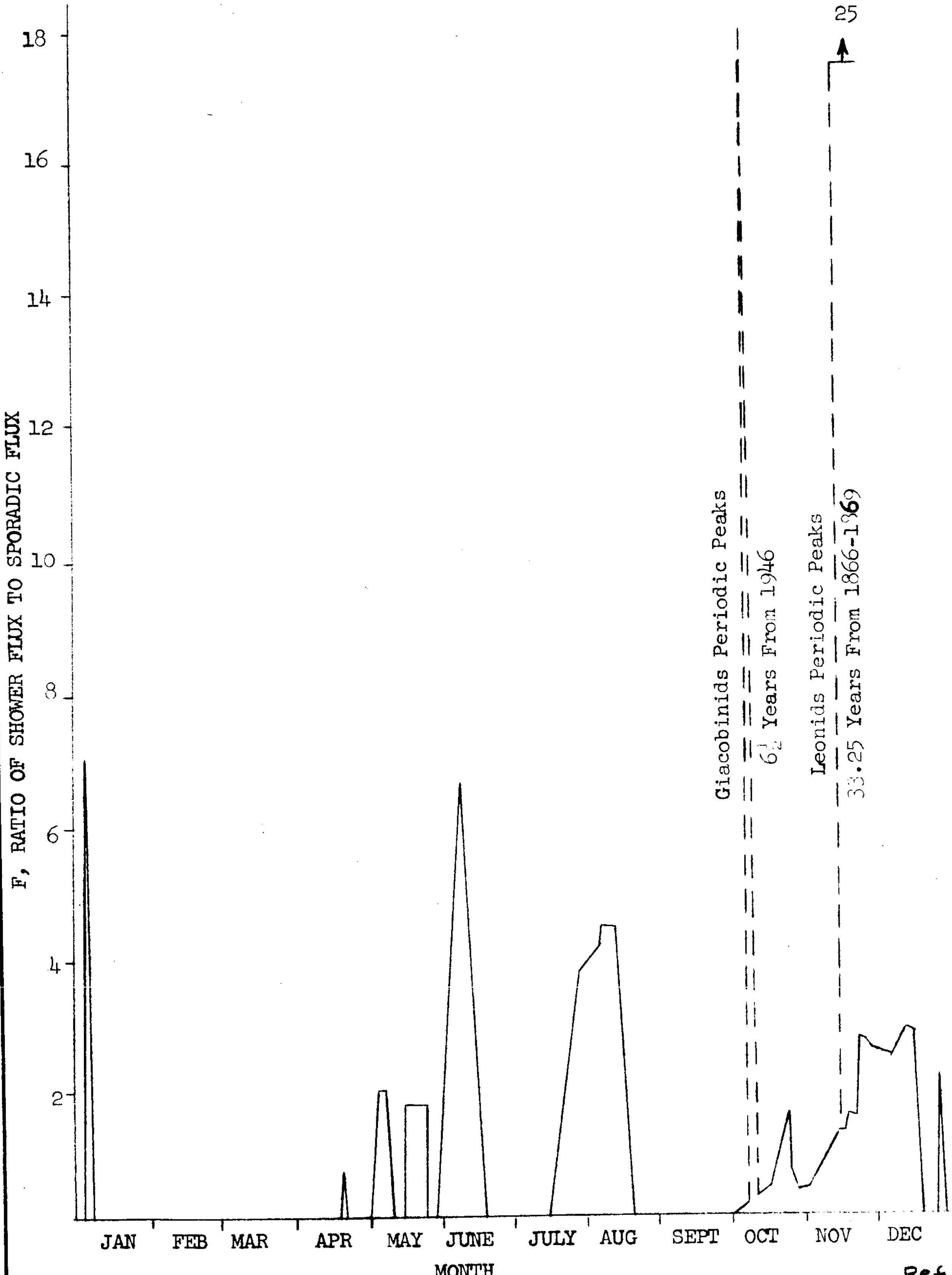


FIG 3 Cross section of model lunar surface

* ref paragraph 4.3.4.1

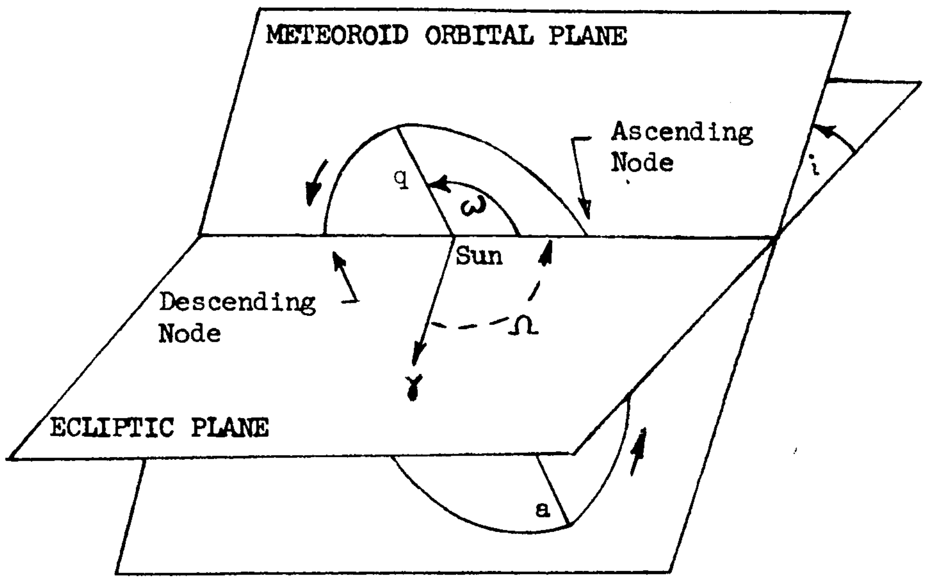
FIGURE 4
RATIO OF ACCUMULATIVE SHOWER FLUX
TO THE SPORADIC FLUX FOR A CALENDAR YEAR



Ref 15

FIGURE 5

DEFINITION OF SYMBOLS



e = eccentricity of orbit

q = perihelion distance (astronomical units)

a = semi major axis (astronomical units)

Ω = longitude of ascending node

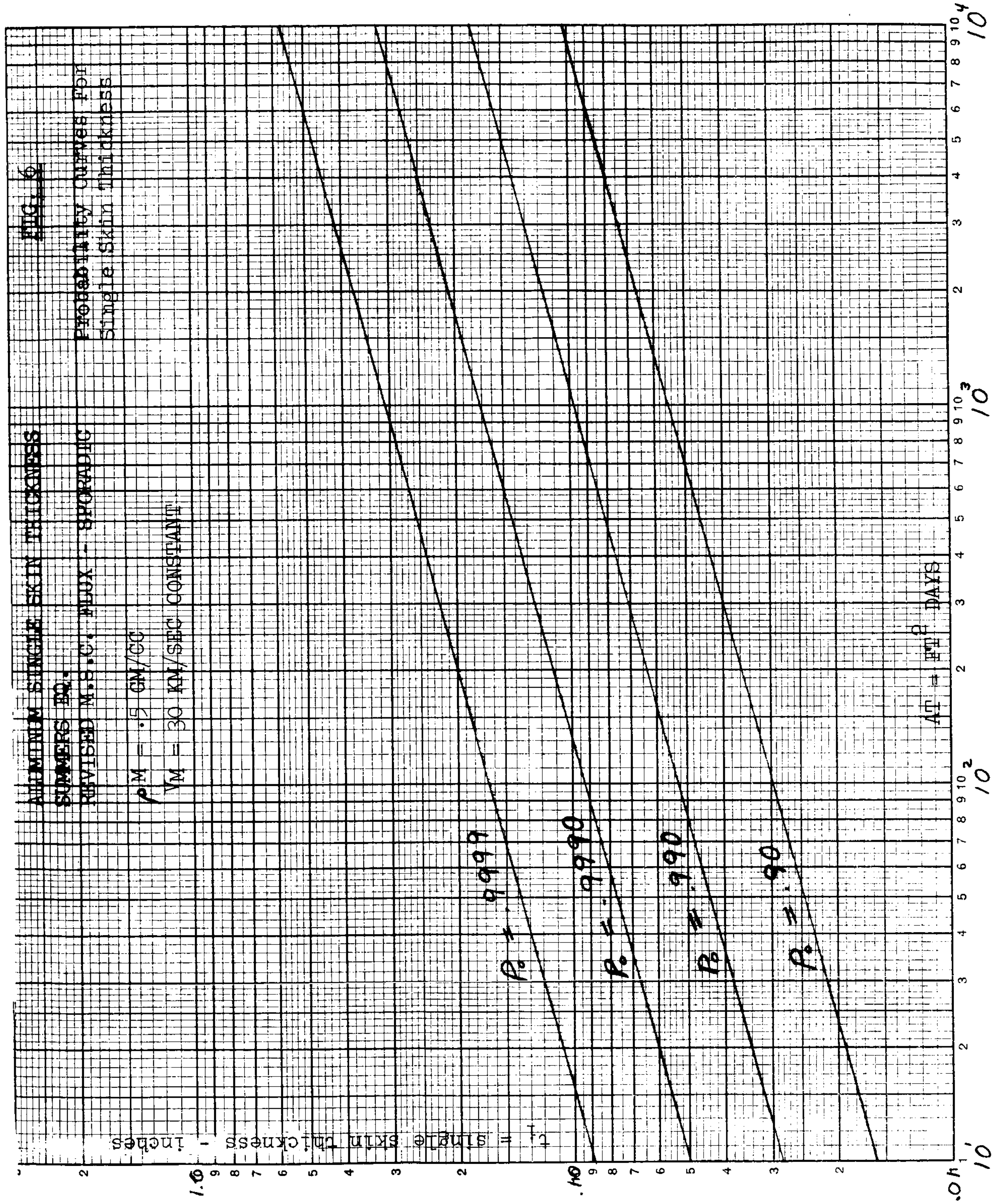
ω = latitude of perihelion

i = inclination of meteoroid orbital plane

γ = reference point (vernal equinox)

π = longitude of perihelion

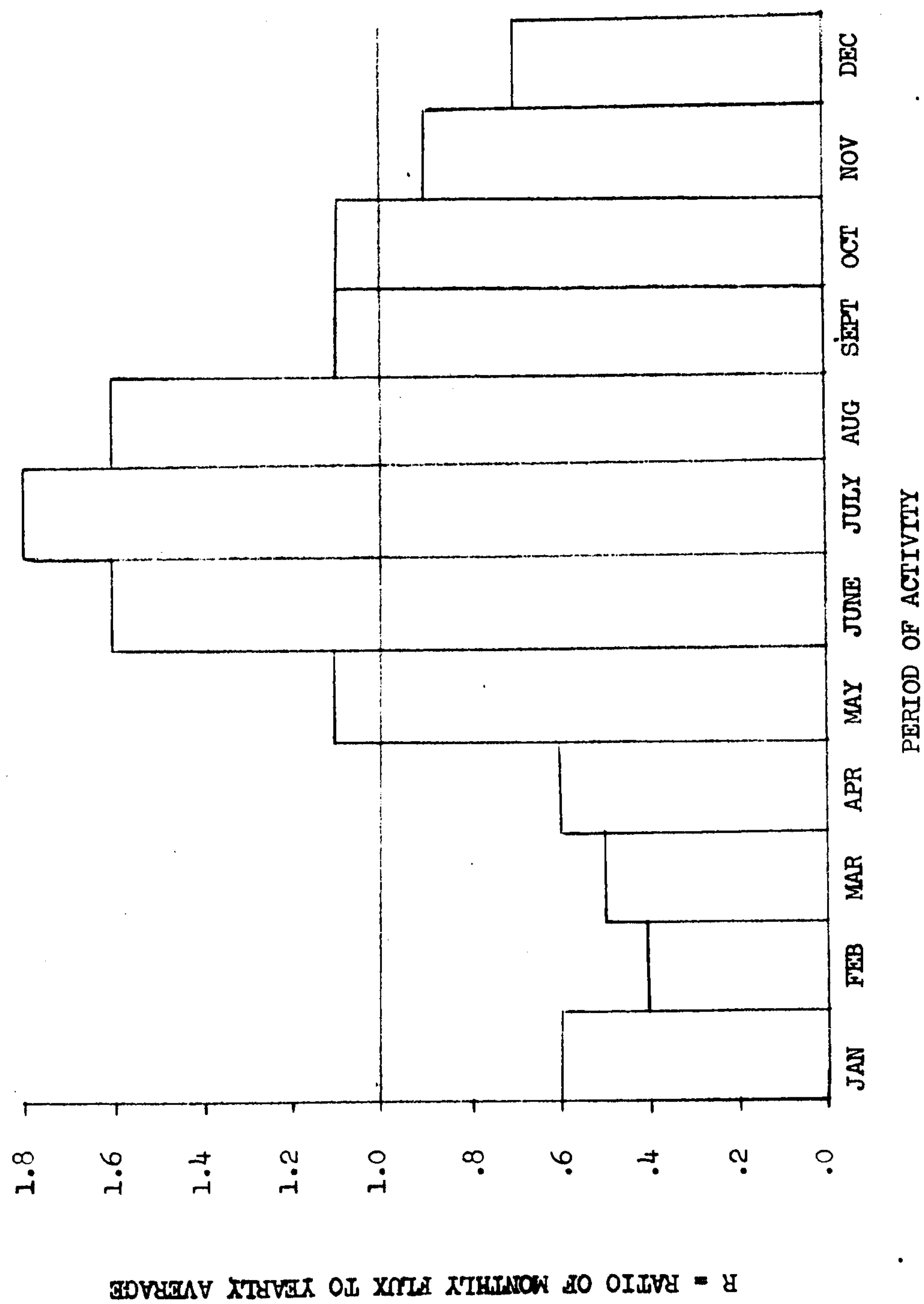
Ref. 15



Code 26512 Eng-23A

Ref. 15

FIGURE 7 - MONTHLY VARIATION OF SPORADIC FLUX



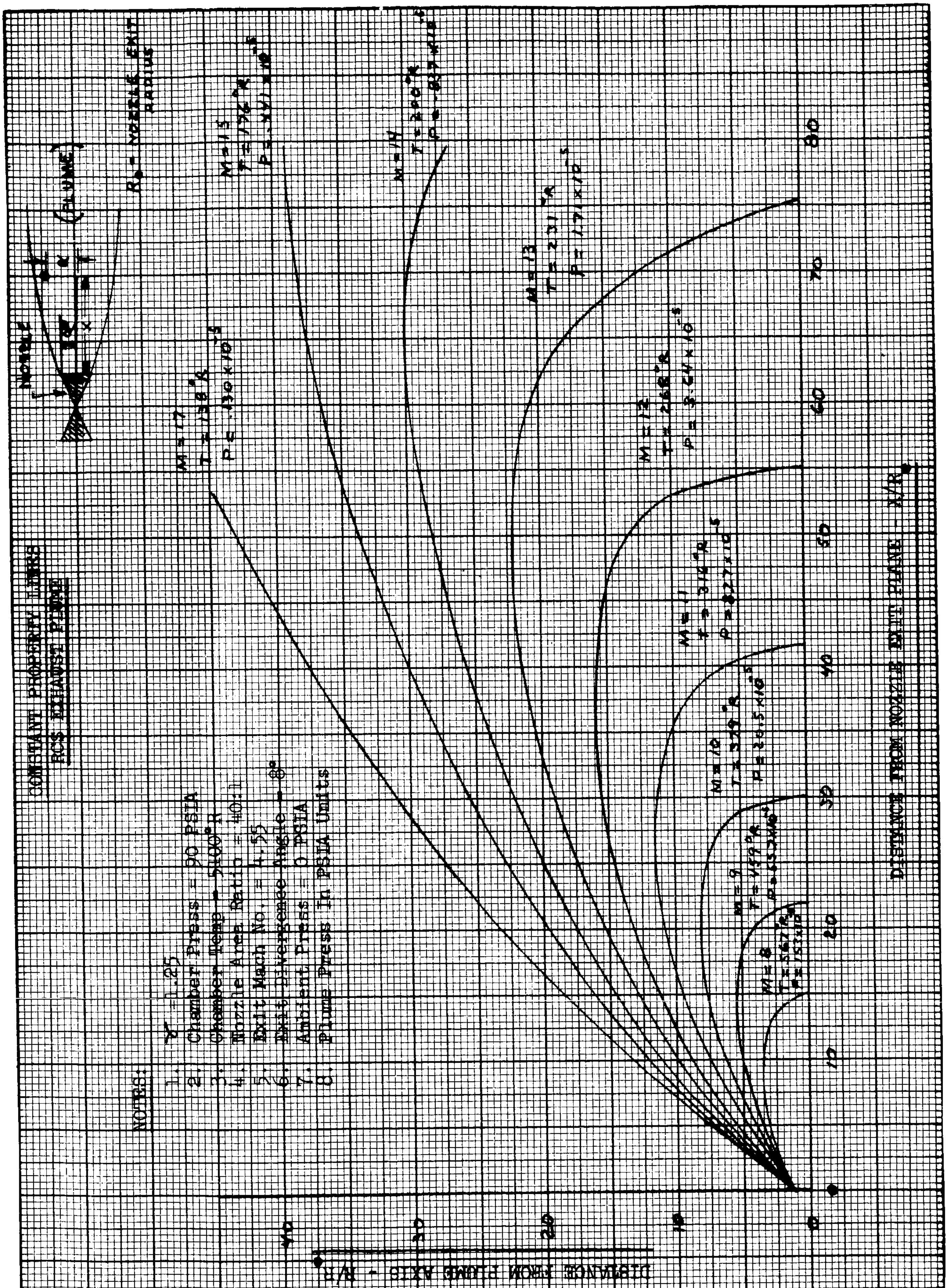

CONSTANT PROPERTY LINES
RCS EXHAUST PLUME
NOZZLE
(PLUME)
R_e = NOZZLE EXIT RADIUS
NOTES:
1. γ = 1.25
2. Chamber Press = 90 PSIA
3. Chamber Temp = 5100°R
4. Nozzle Area Ratio = 40:1
5. Exit Mach No. = 4.55
6. Exit Divergence Angle = 8°
7. Ambient Press = 0 PSIA
8. Plume Press In PSIA Units
M = 17 T = 138°R P = .130 × 10^-5
M = 15 T = 176°R
M = 14 T = 200°R
M = 13 T = 231°R P = 1.71 × 10^-5
M = 12 T = 268°R P = 3.64 × 10^-5
M = 11 T = 312°R P = 8.27 × 10^-5
M = 10 T = 379°R P = 20.5 × 10^-5
M = 9 T = 459°R P = 65.2 × 10^-5
M = 8 T = 567°R P = 153 × 10^-5
DISTANCE FROM PLUME AXIS - R/R
DISTANCE FROM NOZZLE EXIT PLANE - X/R
0
10
20
30
40
50
60
70
80

	Table I LEM Mission Times (L) Normal Mission	LEM Sys's. on	LEM Crew	Time Nominal (MP)
1.1	Acceptance and other tests	-	-	-
1.2	Countdown	all	None	600M
1.3	Holds			
2.	Launch and Earth Ascent	"	"	12M
3.	Earth Orbit (90 Minutes/Orbit)	"	"	270M
4.	Translunar Insertion	"	"	5M
5.	Initial Coast - to Clear Inner Belt	"	"	20M
6.	Transposition (Jettison S IV B)	"	"	40M
7.	Translunar Check Out	-	One	60M
8.	Continue Translunar Trip	None	None	6480M
	2-8 (Launch and Translunar)			6887M 114.78H
9.	Insertion into 80 N.M. Lunar Orbit	"	"	6M
10.	Coast in Orbit	"	"	150M
11.	LEM Check Out and Alignment	all	Two	90M
	9-11 (Lunar Orbit)			246M 4.1H
12.	Separate 100 feet	"	"	1.3M
13.	Orient LEM and prepare for Descent	"	"	13.2M
14.	Insert into Elliptical Orbit (Sync)	"	"	D. 0.5M
15.	Coast to 50,000 ft. Pericynthion	"	"	60.0M
16.	Retro to 20 N. Mi. of Landing Site	"	"	D. 4.0M
17.	Final Powered Descent to 1000 ft.	"	"	D. 2.5M
18.	Hover to Touchdown	"	"	D. 2.0M
	12-18 (Lunar Descent)			83.5M 1.39H (1)
19.	Lunar Stay			35H (1)
20.	Powered Ascent to 50,000 Circ. Orbit	"	"	A. 7.3M
21.	Orbit Contingency - Coast in 50,000 Orbit	"	"	0M
22.	Insert into Intercept Transfer Orbit	"	"	A. 0.1M
23.	Coast in Transfer Orbit	"	"	90M
24.	Rendezvous form 30 N.M. to 500 ft.	"	"	24M
25.	Dock from 500 ft. to Contact	"	"	15M
26.	Transfer Crew	"	None	20M
	20-26			156.4M 2.61H (1)
	2-26			157.38H
D.	Descent Engine Operating Time (Not including (135) seconds prelaunch check) (Duty cycle time in Engine Spec. = 730 seconds)			9M
A.	Ascent Engine Operating Time (Not including (60) Seconds prelaunch check)(Duty cycle time in Engine Spec. = 445 sec.)			7.4M
(L.)	LEM lifetime - See page 2 (ref. 16) Sum of (1) Total (from earth launch)(ref. 16) 166.88H* (from earth launch) nominal in days =			48H 157.88H 6.57Days
(M.P.)	Mission Phase (ref. 16)			
*	includes 9 hour orbit contingency after Lunar Stay			
M	Minutes			
H	Hours			

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

Notes: 1. Factors of safety are not included in the levels specified herein and shall be applied to these values and self-generated structural loads of each subsystem. The levels given are the maximum expected.

a. LEM/or individual items ref. 3.2

b. Ground equipment ref. 3.4

2. All accelerations are "earth g's". Multiply by earth weight or use 32.2 ft/sec.^{2} as appropriate.(sign conv. - page 28)

3. Vibrational spectra shown gives straight lines on a log-log plot.

4. Packaged and unpackaged - Pre-launch transportation handling and storage type of package.

5. Cabin - this includes the crew compartment and the equipment tunnel that will be pressurized.

6. Equipment bay - Equipment bay in either the Ascent stage or Descent stage external to the cabin.

7. Radiation - applied to external and internal items. Ref. para. 4.0 and 4.1.

8. Meteoroids - applies to external items only. Ref. para. 4.2 4.2.1, 4.2.2 and 4.2.3.

9. External surface of the LEM - this is the heat shield.

10. Plume induced environments.

a. RCS - as per paragraph 4.1.2.3

b. Engines - will be specified

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(a) Pre-Launch - Packaged(*)

Transportation, handling and storage in shipping container shall not produce critical design loads on the LEM and shall not increase weight of the LEM.

Acceleration:	(ns)	2.67 g vertical with 1.0 lateral, applied to the package.
	(v)	1.0 g vertical
	(ns)	2.0 g in direction of hoisting (when rings are used, consider applied to any one or any combination of rings).
Shock:	(ns)	Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516 Procedure III, (Except; LEM Vehicle, which is to be supplied).*
Vibration:	(ns)	The following vibration levels are specified during transportation, handling and storage. Vibration to be applied, along three mutually perpendicular axes, x, y, and Z to the package.

(Time: 1/2 Octave per minute, three times per axis from 5 cps to max cps and back to 5 cps).

For 100 lb. or less		For 300 lb. or more	
cps	g or D.A.	cps	g or D.A.
5-7.2	.5 in D.A.	5-7.2	.5 in D.A.
7.2-26	±1.3 g	7.2-26	±1.3 g
26-52	.036 D.A.	26-52	.036 D.A.
52-500	±5.0 g	---	
(f)		(f)	

(f) for 100 to 300 lbs - use figure 514-8 Method 514 MIL-STD 810 (USAF) 14 June 1962 for maximum frequency.

* Pressure	Atmospheric pressure corresponding to sea level to 50,000 feet.
Temperature	-65°F to +160°F.

(*) For packaged in special container (reuseable) see LSP-420-001 - applies to Engines, Fuel Cell, and components of RCS, and ECS.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(a) Pre-Launch - Packaged (Continued)

*	Humidity:	(nc)	0 to 100 percent relative humidity including condensation.
*	Rain:	(nc)	Rain as defined in Method 506 MIL-STD 810 (USAF) 14 June 1962.
*	Salt Spray:	(nc)	Salt Spray as encountered in a beach area (equivalent to spray of 5% salt solution in water for 50 hours).
*	Sand and Dust	(nc)	As in desert and/beach areas, equivalent to 140 mesh screen silica flour up to 500 ft/min (up to 2000 at WSMR) at 70° ±20°F as in Method 510 MIL-STD 810.
	Fungus:		In accordance with Method 508, MIL-STD-810 (USAF) 14 June 1962.
*	Ozone	(nc)	Exposure with 0.05 parts/million concentration (1/2 toxic limit).
*	Hazardous Gases		Explosion exposure as defined in Method 511, MIL-STD-810 (USAF) 14 June 1962.
*	Electromagnetic Interference:		In accordance with LSP-530-001.

		(v)	Earth gravity compensation is not required.
		(ns)	Not simultaneous loading conditions at these levels.
		(nc)	Not simultaneous environment conditions at these levels.
*			Ambient environment on outside of package.

TABEL II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b) Pre-Launch - Unpackaged

Accelerations	(v)	1.0 g vertical
	(ns)	2.67 g Vertical with 1.0 g Lateral
	(ns)	2.0 g in direction of hoisting
Shock	(ns)	Shock as in MIL-STD-810 (USAF) 14 June 1962 Method 516, Procedure I Modified. Modify shockpulse to sawtooth 15 g peak 10-12ms rise, 0-2ms decay. (Except LEM vehicle which is to be supplied.
Vibration	(ns)	Same as pre-launch packaged but applied to item.
Pressure		Ambient ground level pressure. (Hermetically sealed units installed in the crew compartment will be subjected to a limit pressure of 20 psi absolute during preflight checkout).
Temperature		-20°F to 110°F Ambient Air Temperature plus 360 BTU/FT^{2}HR up to 6 hr/day.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(b) Pre-Launch Unpackaged (Cont'd)

Humidity	(nc)	15% to 100% relative humidity including condensation.
Rain	(nc)	Same as packaged but no direct impingement
Salt Fog	(nc)	As in MIL-STD-810 (USAF) Method 509.
Sand and Dust	(nc)	Same as Pre-Launch Packaged
Fungus		Same as Pre-Launch Packaged
Ozone	(nc)	Same as Pre-Launch Packaged
Hazardous gases		Same as Pre-Launch Packaged
Electromagnetic Inteference		Same as Pre-Launch Packaged

(v) See page 39
(ns) " " "
(nc) " " "

TABLE II

ENVIRONMENTAL CONDITIONS

(c) Prelaunch - Unpackaged - Equipment Operating

Acceleration: Not applicable.

Random Vibration: Random vibration shall be 75 seconds for each of the three mutually perpendicular axes; x, y and z.

Input to equipment supports from primary structure.

10-28	cps	.18 g^2/cps Constant
28-37	cps	12 db/octave decrease to
37-1000	cps	.059 g^2/cps constant
1000-1200	cps	12 db/octave decrease to.
1200-2000	cps	.031 g^2/cps constant

Sinusoidal Vibration: Not applicable

Acoustics: (to be supplied)

Pressure: 5.8 psig O_2 in cabin, atmospheric pressure corresponding to sea level to 150,000 feet during engine firing.

Thermal Vacuum (To be supplied)

TABLE II

ENVIRONMENTAL CONDITIONS

(c) Prelaunch - Unpackaged - Equipment Operating (Con'd)

Temperature:	Same as pre-launch unpackaged
Humidity:	Same as pre-launch unpackaged
Rain:	(to be supplied)
Salt Spray:	Not applicable
Sand and Dust	Not applicable
Fungus:	Not applicable
Ozone:	Not applicable
Hazardous Gas:	(to be supplied)
Hazardous Liquid:	(to be supplied)

Electromagnetic Interference: Same as pre-launch packaged.

Reaction Control Thrusters, ascent, and descent engine firing: (to be supplied)

Exhaust Temperature	"
BTU/ft^2/second	"
Exhaust gas composition	"
Exhaust Mock No	"
Exhaust pressure	"

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Launch and Boost C-5

Acceleration (2)

	X		Y		Z	
	g	Rad/Sec²	g	Rad/Sec²	g	Rad/Sec²
Boost Condition (S-1C)	+4.7	-	±.1	-	±.1	-
Max. q Condition (S-1C)	+2.1	-	±.5	-	±.5	-
Cut Off Condition (S-1C)	-2.6	-	±.1	-	±.1	-
Engine Hardover (S-11)	+2.3	-	±.63	-	-	-
Engine Hardover (S-11)	+2.3	-	-	-	±.63	-
Earth Orbit	0	0	0	0	0	0

Vibration: The mission environment consists of the following random spectrum, (a) or (b) applied for 17 minutes along each of the three mutually perpendicular axes, X, Y and Z.

(a) Input to equipment supports from exterior primary structure.

5-13 cps	.18 g^2/cps Constant
13-15 cps	12 db/Octave rise to
15-32 cps	.30 g^2/cps Constant
32-49 cps	12 db/Octave Decrease to
49-950 cps	.044 g^2/cps Constant
950-1200 cps	12 db/Octave decrease to
1200-2000 cps	.015 g^2/cps Constant

(b) Input to equipment supports from interior primary structure.

5-27 cps	.18 g^2/cps Constant
27-40 cps	12 db/Octave decrease to
40-2000cps	.036 g^2/cps Constant

(2) Para. 2.3.2 — S IV B Ignition prior to Earth Orbit & reignition for translunar Boost.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(d) Launch and Boost C-5 (Continued)

	Octave Band (cps)	C5 at max. q Level (db)
Acoustics: (sound pressure levels in d. b. external to LEM) (re .0002 dynes/cm^2)	9 to 18.8	142
	18.8 to 37.5	141
	37.5 to 75	141
	75 to 150	138
	150 to 300	134
	300 to 600	130
	600 to 1200	123
	1200 to 2400	116
	2400 to 4800	110
	4800 to 9600	104
	overall	147

Pressure:	Atmospheric pressure at sea level to 1×10^{-8} mm Hg (N_2), except in cabin which is pure oxygen 20.5 psia to 5.8 psia
Temperature:	0 to 160°F uncontrolled cabin 0 to 160°F equipment bay 40° to 100°F propulsion comportment +15 to 100°F ambient sea level - AMR -65 to 165°F LEM external surface
Humidity:	"none"
Hazardous gases:	Same as pre-launch packaged
Electromagnetic Interface:	Same as pre-launch packaged
Radiation:	See Paragraph 4.1.
Meteoroids:	Flux as specified in Table V, (for external items). (ref. 4.2.3)
Checkout:	See prelaunch unpackaged operating

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(e) Space Flight - Translunar

	X		Y		Z	
	g	Rad/Sec^2	g	Rad/Sec^2	g	Rad/Sec^2
Acceleration:						
SM prop. system operating	-.45	-	±.11	± .26	±.11	± .26
SM prop. sys. not operating	0	0	0	0	0	0
Shock:						
condition transposition	-.84	-	±.085	±12.0	±.085	±12.0

Vibration:
SM prop. system operating

The mission environment consists of the following random spectrum applied for 6 minutes along each of the three mutually perpendicular axes, X, Y and Z.

Input to equipment supports from primary structure.

5 - 47 cps.	.089 g^2/cps constant
47 - 65 cps.	12db/octave decrease to
65 - 1000 cps.	.024 g^2/cps constant
1000 - 2000 cps.	12 db/octave decrease

Plume effects:

Due to Engines to be supplied.
Due to RCS in accordance with para. 4.1.2.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(e) Space Flight Translunar (Con'd)

Pressure:	1 x 10^{-14} mm Hg uncontrolled vacuum (space) 5.8 psia controlled cabin (O_2) 5.8 to .1 psia uncontrolled cabin (O_2) 1 x 10^{-9}mm Hg uncontrolled vacuum (LEM Descent stage) 1 x 10^{-10}mm Hg uncontrolled vacuum (LEM ascent stage)
Temperature: **	0 to +160°F uncontrolled cabin 0 to +160°F equipment bays 70 to 80°F controlled cabin 40 to 100°F propulsion bays -15° to +175°F around fuel cell +260° to -260°F external surface For external items: Solar radiation = 440 BTU/ft^2hr. Lunar surface: +250°F to -300°F (depending on Sun's position) Space = -460°F.
Humidity:	40 to 70% in controlled cabin 0 to 100% uncontrolled cabin
Ozone:	To be determined
Hazardous Gas:	Same as pre-launch packaged
Electromagnetic Interference:	Same as pre-launch packaged
Radiation:	Van Allen, Solar Flare and Space background. To be defined as needed (inner belt 10 minutes 1/2 hr. delay - outer belt 20) (See paragraph 4.1).
Meteoroids:	Use distribution for sporadic meteoroids, in accordance with Table V. (for external items) paragraph 4.2.1.

**Equipment temperature due to combined exposure shall be determined for external items.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Descent - Including separation, descent, hover and touchdown

	X		Y		Z	
Accelerations:	g	rad/sec^2	g	rad/sec^2	g	rad/sec^2
Descent engine operating	+1.1	±.31	±.11	±.47	±.11	±.47
Transfer Orbit	0	0	0	0	0	0
Landing(to be supplied)						
Shock:						
Landing						
10-20 ms rise time - ramp step shock (preliminary)						
Case 1	8.0			±14.0		
Case 2			±8.0			±14.0
Case 3				±14.0	±8.0	
Case 4	8.0					±14.0

Vibration: Descent Engine Operating

The mission environment consists of the following random spectrum applied for 11½ minutes along each of the mutually perpendicular axes, x, y and z.

Input to equipment supports from primary structure.

10 - 28 cps	.18 g^2/cps constant
28 - 37 cps	12 db/octave decrease to
37 - 1000 cps	.059 g^2/cps constant
1000 - 1200 cps	12db/octave decrease to
1200 - 2000 cps	.031 g^2/cps constant

Plume effects: Due to Engines to be supplied.
Due to RCS in accordance with para. 4.1.2.3

Pressure:
$\leq 1 \times 10^{-10}$ mm Hg uncontrolled vacuum
4.8 to 5.8 psia controlled cabin.
1×10^{-9} mm Hg uncontrolled vacuum (LEM Descent stage)
1×10^{-10} mm Hg uncontrolled vacuum (LEM Ascent stage)

Temperature **, *
0 to +160°F equipment bays
+40 to +100°F propulsion bays
50° to 90°F cabin - local spots
+70 to +80°F cabin - average
-15 to +175°F around fuel cell
+260 to -260°F external surface

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(f) Lunar Descent (continued)

Temperature (continued) **, *	For external items: Solar radiation = 440 BTU/FT^2/hr. Lunar surface +250 to -300°F depending on suns position - Space = -460°F
Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h.
Ozone:	To be determined.
Hazardous Gas:	Same as pre-launch packaged.
Electromagnetic Interference:	Same as pre-launch packaged.
Meteoroids:	Use distribution for sporadic meteoroids as specified in Table V (for external items) (paragraph 4.2.3)
Sand and Dust:	This is to be specified by Grumman
Radiation:	See Paragraph 4.1.

** Equipment temperature due to combined exposure shall be determined for external items.

* The backface temperature of the Descent Engine Combustion Chamber is $\leq$400°F. The heat shield prevents the internal cavity LEM structure from seeing this.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Stay

Accelerations:	X
cond. - at rest	1/6 g
Shock:	Not critical

NOTES: Ascent and descent engines not operating. Vibration due to other sources to be supplied.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(g) Lunar Stay (Con'd)

Pressure:	1×10^{-12} mm Hg uncontrolled vacuum (surface of moon) 5.8 psia (O_2) controlled cabin 1×10^{-9} mm Hg cabin (hatch open) 1×10^{-9} mm Hg uncontrolled vacuum (LEM Descent stage) 1×10^{-10} mm Hg uncontrolled vacuum (LEM Ascent stage)
Temperature:	0 to +160°F equipment bays 40 to +100°F propulsion bays - 50 to 90°F cabin local spots - 70 to 80°F cabin average 70 to 80°F cabin (hatch open)(preliminary) -15 to +175°F around fuel cell +260 to -260°F - external surface For external items: Solar radiation = 440 BTU/Ft^2hr. Lunar surface +250 to -300°F depending on suns position Space = -460°F
Humidity:	Controlled cabin (O_2) 40 - 70% rel. hum. Avg. locally in cabin (O_2) 0 = 100% rel. humidity
Ozone:	To be determined.
Hazardous Gas:	Same as pre-launch packaged.
Radiation:	Solar flare and space background to be defined as needed. See paragraph 4.1.1
Electromagnetic Interference:	Same as packaged pre-launch.
Meteoroids:	Use distribution for sporadic meteoroids as specified in Table V (for external items). (Ref. 4.2.1)
Sand and Dust:	This is to be specified by Grumman.

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(h) Lunar Ascent - Including ascent rendezvous and docking

Acceleration:	X		Y		Z	
	g	rad/sec^2	g	rad/sec^2	g	rad/sec^2
engine operating	+1.0	±.88	±.05	±.88	±.05	±2.0
docking condition	0	0	0	0	-4.0	0
transfer orbit	0	0	0	0	0	0
Shock:	To Be Supplied by Grumman					

Vibration:
engine operating

The mission environment consists of the following random spectrum applied for 8½ minutes along each of the three mutually perpendicular axes, x, y and z.

Input to equipment supports from primary structure.

10-28 cps	.18 g^2/cps constant
28-37 cps	12db/octave decrease to
37-1000 cps	.059 g^2/cps constant
1000-1200 cps	12db/octave decrease to
1200-2000 cps	.031 g^2/cps constant

Plume Effects:

Due to Engines to be supplied.
Due to RCS in accordance with paragraph 4.1.2.3..

TABLE II

MISSION LEVELS

ENVIRONMENTAL AND LOAD CONDITIONS

(h) Lunar Ascent -

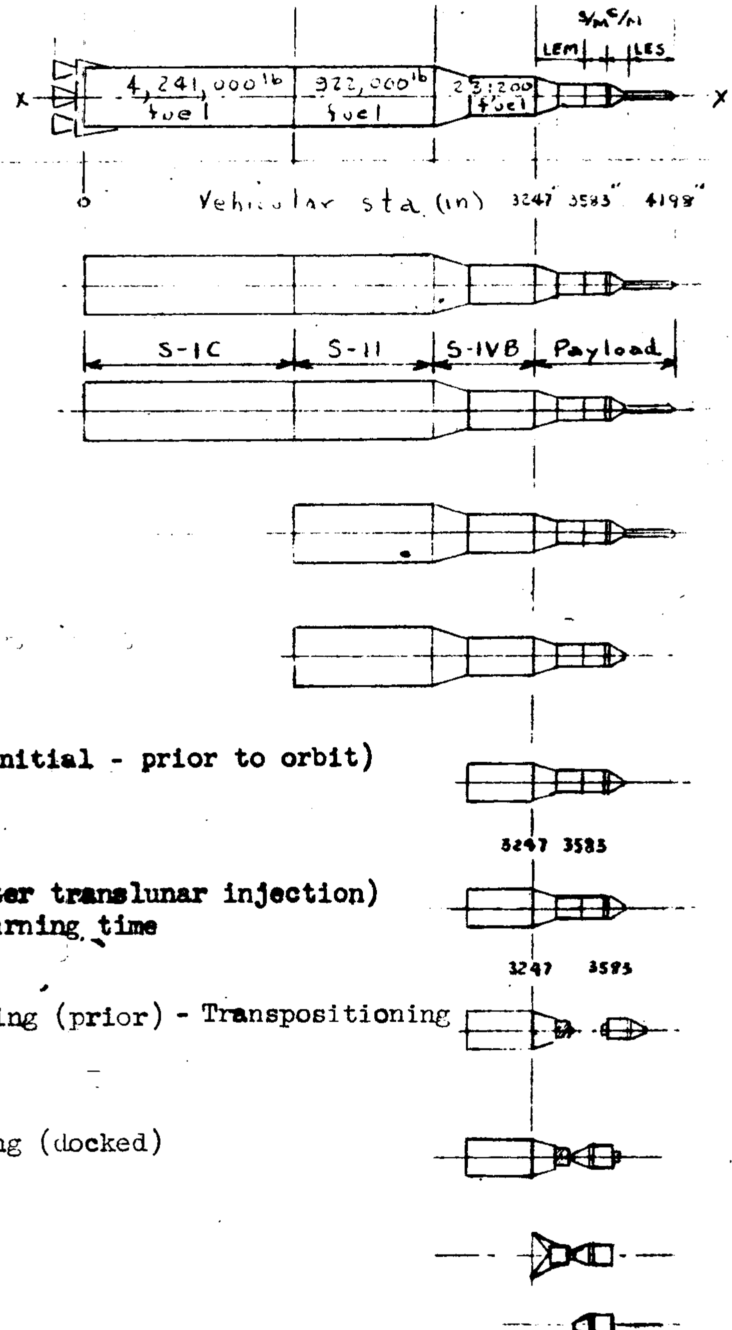
Pressure:	1 x 10^{-12} mm Hg uncontrolled vacuum (space) 4.3 to 5.8 psia controlled cabin 1 x 10^{-10} mm Hg uncontrolled vacuum (LEM Ascent stg)
Temperature **, *	0 to +160°F equipment bays +40 to +100°F propulsion bays 50° to 90°F cabin - local spots +70 to +80°F cabin - average -15 to +175°F Around Fuel Cell + 260 to -260°F external surface + 400°F for 5 minutes, external separation surface For external items: Solar radiation = 440 BTU/FT^2/hr. Lunar surface +250 to -300°F depending on Sun's position - Space = -460°F
Humidity:	Controlled cabin (O_2), 40 to 70% r.h. Locally in cabin (O_2), 0 to 100% r.h.
Ozone:	To be determined.
Hazardous Gas:	Same as pre-launch packaged.
Electromagnetic Interference:	Same as pre-launch packaged.
Meteoroids:	Use distribution for sporadic meteoroids as specified in Table V (for external items) (paragraph 4.2.3)
Sand and Dust:	This is to be specified by Grumman
Radiation:	See Paragraph 4.1.

** Equipment temperature due to combined exposure shall be determined for external items.

* The backface temperature of the Ascent Engine Combustion Chamber is to be supplied.

TABLE III

TABLE III



	Weight lb's	C. G. inches Vehicular Stations	Iy slug - ft^2
S-IC lift off t=0	6,000,000	1249	758×10^6*
S-1C, Max. q t = 65 sec.	3,391,600	1377*	737×10^6*
S-1C, Burnout t = 130 sec.	1,759,000	1918*	279×10^6*
S-11, Ignition t = 130	1,376,000	2220*	91.9×10^6*
S-11, Burnout t = 539 sec.	453,450	2834*	32.2×10^6*
S-IV B, Ignition (initial - prior to orbit)	353,630	3004*	9,980,000*
S-IV B, Burnout (after translunar injection) 480 sec. burning time	122,430	3375*	3,850,000*
S-IV B, Initial docking (prior) - Transpositioning	(to be supplied)		
S-IV B Initial Docking (docked)			
Space Craft			
C/M and S/M			

* GAEC Approximations only.

TABLE III (CONT'D)

LEM MASS PROPERTY HISTORY

LEM TENTATIVE DESIGN WEIGHT

Ref. LMO-490-26
7 August 1963
Page 2

MISSION PHASE	WEIGHT EARTH POUNDS	CENTER OF GRAVITY			MOMENTS OF INERTIA			PRODUCTS OF INERTIA		
		STATION INCHES	DISTANCE FROM THRUST AXIS		SLUG FT^2			SLUG FT^2		
		X	Y	Z	I_{xx}	I_{yy}	I_{zz}	I_{yz}	I_{xz}	I_{xy}
EARTH LAUNCH	26,402	186.1	-.1	-1.4	17,246	19,724	18,913	-191	-290	17
SEPARATION	26,800	187.8	-.1	- .5	18,158	20,181	19,247	-191	55	19
SYNCHRONOUS ORBIT	25,713	188.0	-.1	- .5	17,412	19,694	18,918	-191	55	19
HOVER	13,056	212.4	-.2	-1.0	8,726	10,663	11,671	-192	125	34
TOUCHDOWN	11,961	218.6	-.2	-1.1	8,007	8,937	10,079	-192	-142	37
PRE-LIFT OFF	11,791	218.8	0	-1.0	7,926	8,867	9,981	-192	147	12
LIFT OFF	8,100	245.4	.1	-1.5	4,738	2,935	4,083	- 84	232	-11
TRANSFER ORBIT 50,000 Ft. to 80 Miles	4,079	244.4	.2	-2.9	2,643	2,284	1,477	- 84	229	-11
BURNOUT (DOCKED)	3,739	245.9	.2	- .3	2,322	2,243	1,128	- 84	232	-11
POST - BURNOUT	3,153	244.5	.3	-10.5	1,976	1,889	1,001	- 83	188	-11

Sign convention positive directions as on page 23

TABLE IV

ACCELERATION DUE TO BOOSTER LIMIT LOADS

	Booster	NOTE	Weight - lbs. Ignition	Weight - lbs. Cut-Off	Thrust - lbs. Ignition	Thrust - lbs. Cut-Off	Accelerations: Longitudinal g's Minimum	Longitudinal g's Maximum	Lateral g's Y	Lateral g's Z	Rad/Sec² Y	Rad/Sec² Z
C-1B	S-IA		199,080	381,210	1,504,000	1,730,000	1.25	5.43(1)	---	---	--	
	S-IVB		256,100	51,900(5)	--	200,000	.78	3.85	---	---	--	
C-5	S-IC	(2)	6,000,000	1,758,700	7,500,000	8,630,000	1.25	4.7	±.1	±.1	--	
	S-IC(max.q)	(2)	--	--	--	--	--	2.1	±.5	±.5	--	
	S-IC(c/o)(7)	(2)	--	--	--	--	--	-2.6	±.1	±.1	--	
	S-II		1,376,050	447,850	--	1,000,000	.73	2.90(3)	--	---	--	
	S-IVB		360,050	128,850(6)	--	200,000	.56	1.87(1)	---	---	--	
C-5 (Engine Hard-Over)	S-IC b/o		--	1,758,700	--	8,630,000	--	--	---	---	--	
	S-11 b/o([illegible])		--	447,850	--	1,000,000	--	2.3	±.63	- -	--	
	S-IVB b/o		--	128,850	--	200,000	--	1.87(1)	±.23	±.23	±.70	±.70
	S-1[illegible] b/o([illegible])			447,850		1,000,000		2.3	- -	±.63		

Notes:
(1) Includes 1.2 dynamic amplification.
(2) Ref. TWX 234 and TWX 242 from NASA/MSC rec'd at Grumman 19 June 1963, 14 Oct. 1963.
(3) Ref. NASA Exhibit B - Technical Approach, 20 December, 1962 (Figure 44)
(4) Booster Burnout Wt. = 29,750, Payload Wt. = 25,500 including fairing and adapter.
(5) Second stage jettison weight = 25,180, Payload weight = 26,720.
(6) Third stage jettison weight = 36,500, Payload weight = 92,350 including adapter
(7) At end of first stage thrust, longitudinal springback.

b/o Burn out

c/o Cut Off

TABLE V A - ORBITAL ELEMENTS FOR MAJOR METEOR STREAMS

Name	Period of Activity	Date Max.	Normal Activity Per Hour	Ω deg.	π deg.	ω deg.	i deg.	ϵ	q a.u.	a a.u.	Velocity Geocentric Km/sec	Period Years
Quadrantids*	Jan 2-4	Jan 3	30	282	92	160	67	0.46	0.97	1.7	42**	13
Lyrid	April 19-22	April 21	7-10	30.5	--	210	81	0.33	0.90	---	43	19.3
η-Aquarid	May 1-8	May 4-6	10-34	45	152	108	162	0.96	0.66	17.95	64	---
O-Cetid	May 14-23	May 14-23	20	233	39±3	211±3	34±7	0.91	0.11	1.3	37	1.5
Arietid	May 29-June 19		10-80	77	106	29±3	21±8	0.94	0.09	1.6	38	1.8
ζ-Perseid	June 1-16		30	73	---	59±2	4±2	0.79	0.35	1.6	29	2.2
β-Taurids	June 24-July 5		20	276	162±4	246±4	9±4	0.86	0.36	2.5	31	3.3
δ-Aquarid	July 26-Aug 5	July 28	15	305	101±2	156±2	24±5	0.96	0.08	1.3	29 35**	3.6
Perseid	July 15-Aug 18	Aug 10-14	50	142	---	155	114	0.96	0.97	23	60	109.5
Giacobinid*	Oct 9-10	Oct 10	200	196	---	172	30.8	0.72	0.99	3.5	23	6.5
Orionid	Oct 15-25	Oct 20-23	10-15	29.3	103	87.3	163	0.92	0.54	6.32	66	
Arietid, Southern	October		8	27	150	122	6	0.35	0.30	1.91	34**	2.64
Taurids, Northern	Oct 26-Nov 22	Nov 1	4	221	160	308	2.5	0.86	0.31	2.16	36**	3.2
Taurids, Night	Nov		10	220	160	300	3	0.86	0.3	2.1	37**	3.3

TABLE V A - ORBITAL ELEMENTS FOR MAJOR METEOR STREAMS

Name	Period Of Activity	Date Max.	Normal Activity Per Hour	Ω deg.	π deg.	ω deg.	i deg.	ϵ	q a.u.	a a.u.	Velocity Geocentric Km/sec	Period Years
Taurids, Southern	Oct 26-Nov 22	Nov 16	4	45	157	112	5.1	0.85	0.36	2.39	36**	3.69
Leonid*	Nov 15-20	Nov 16-17	8-10	234	49	179	162	0.92	0.99	12.8	72	33.25
Bielids*	Nov 15-Dec 6		20-30	250	109	223	13	0.76	0.38	3.6	16	6.6
Geminid	Nov 25-Dec 17	Dec 12-13	20-60	261	--	324	24	0.90	0.14	1.4	35	1.7
Ursids	Dec 20-24	Dec 22	10-40	270	--	210	56±3	1.0	0.92	--	37	

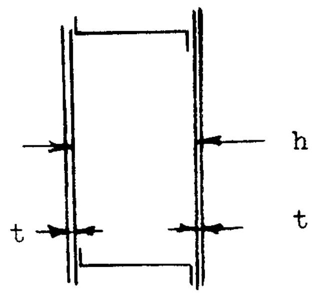
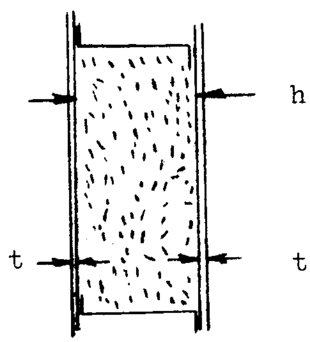
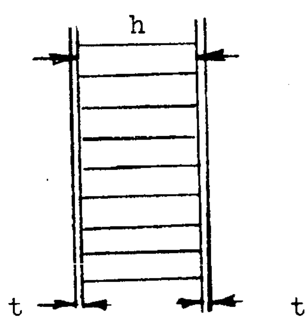
* Periodic streams
** Heliocentric Velocity

NOTE: Appropriate symbols are defined in Figure 5.

Ref. 15

TABLE V B

DOUBLE WALL EFFICIENCY FACTOR

		h	K
	NO CORE	1.0 1.5 2.0	0.50 0.35 0.20
	LOW DENSITY POROUS PLASTIC CORE	1.0 1.5 2.0	0.33 0.25 0.14
	HONEYCOMB CORE NO FILLER	1.0 1.5 2.0	0.67 0.47 0.27

K = EFFICIENCY FACTOR

Ref. 15

REFERENCES

1. NASA Exhibit B - Technical Approach, Contract No. NAS 9-1100, 20 December 1962
2. NASA Project Apollo - LEM Technical Briefing
3. MSFC Drawing No. 10M01071
4. Grumman LSP-530-001
5. ARDC - 1956 Standard Atmosphere
6. MIL-STD-810 (USAF) 14 June 62
7. NASA TWX058 to GAEC dated 6 May 1963.
8. GAEC Telecon LTM-520-16 dated 16 May 1963
9. Grumman - LPL-540-1 dated 15 July 1963 - Mission Analysis
10. NASA Letter SSS/LEM - 63-48 1 April 63
11. NASA Telegraphic Message - SCE-T356/63-62, 7 June 1963
12. Engine Container Spec. LSP-420-001
13. TWX 234 and TWX 242 from NASA/MSC received at Grumman 19 June 1963, 14 October 1963
14. Grumman LED-520-5
15. NASA Letter SLE-13-63-427, dated October 16, 1963
16. NASA LETTER SLE-63-152, dated JUNE 4, 1963